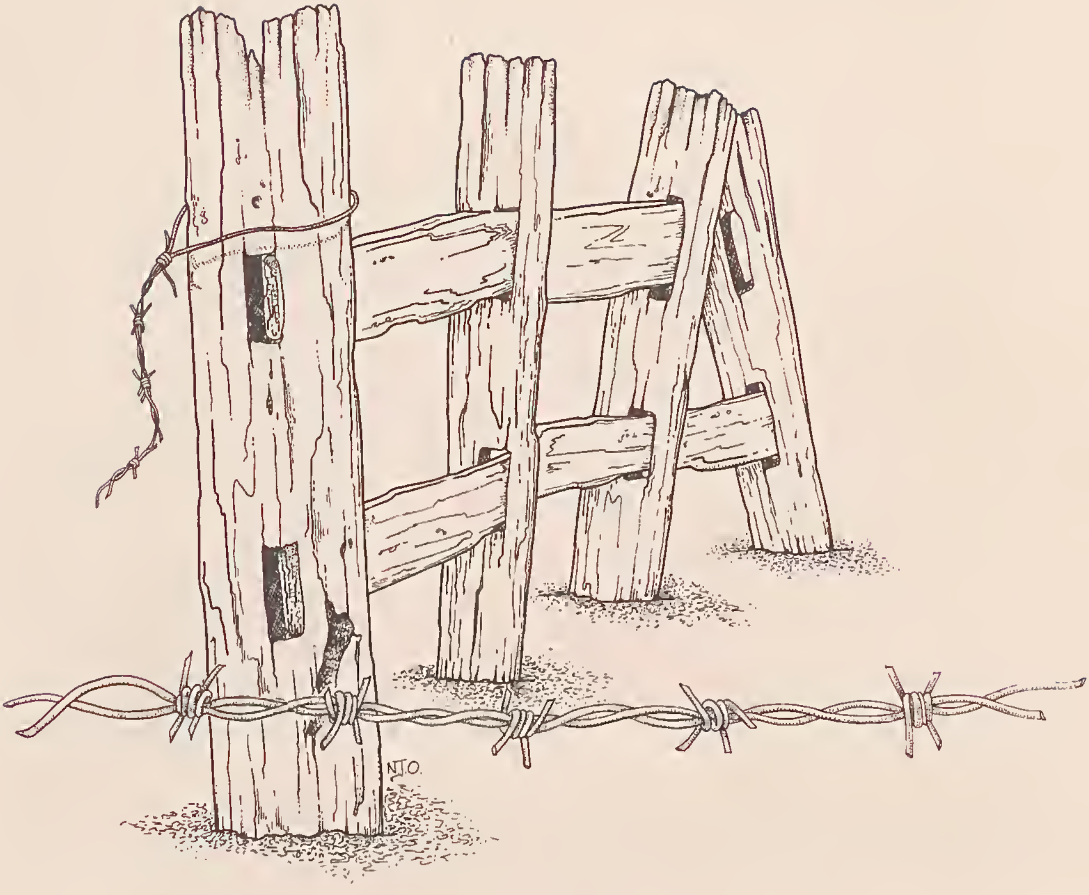
CUNNINGHAMIA

A journal of plant ecology



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Cover
The fencing of the Australian rural landscape allowed easier control of stock and more intensive grazing, but led to soil degradation and loss of biodiversity. On the Monaro, grazing eliminated many palatable forbs and grasses to the extent that only small remnants of native grassland survive. In western NSW, vast numbers of native White Cypress Pine, *Callitris glaucophylla*, were felled for fence posts and telegraph lines.

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CONTENTS

The natural vegetation of north-western New South Wales: notes to accompany the 1: 1 000 000 vegetation map sheet **John Pickard and E.H. Norris** 423

Rainforest stands between Barrington Tops and the Hunter River, New South Wales **J.C. Turner and S.L. Vernon** 465

Observations on the effects of mowing on native species in remnant bushland, western Sydney **T.A. James** 515

The effect of time since fire on the cover and composition of cryptogamic soil crusts on a eucalypt shrubland soil **D.J. Eldridge and R.A. Bradstock** 521

Lost and found: *Nothofagus moorei* at Comboyne **C.L. Bale and J.B. Williams** 529

Observations on the ecology and conservation status of the rare herb *Gentiana wingecarribiensis* **P.G. Kodela, T.A. James and P.D. Hind** 535

Floristics, structure and diversity of natural vegetation in the O'Hares Creek catchment, south of Sydney **David Keith** 543

Performance of halophytes from semi-arid areas on two saline seepage scalds of the Central West Slopes of NSW **W.S. Semple and D. Waterhouse** 595

The native grasslands of the Monaro region: Southern Tablelands of NSW **J.S. Benson** 609

Plant communities of the Monaro lakes **J.S. Benson and S.W.L. Jacobs** 651

Map area

The 1:1 000 000 map area covers the north-western quarter of New South Wales, bounded in the north by the Queensland–New South Wales border (latitude 29° 00′S), in the west by the South Australia–New South Wales border (longitude 141° 00′E) in the south by latitude 33° 00′S, and in the east by longitude 147° 00′E (Fig. 1). The area lies mostly within the Western Division of New South Wales and is approximately 26.6 million hectares (ha) in extent representing 28% of the State. The area is largely within the North-western Plains and North Far-western Plains botanical subdivisions. The map covers sixteen 1:250 000 maps.

Major rivers within the map include the Darling, Paroo, Warrego and Culgoa Rivers and their associated tributaries and distributaries (Fig. 1).

Resident population distribution within the area is largely confined to major centres, in particular the city of Broken Hill with an estimated 52% of the population (Australian

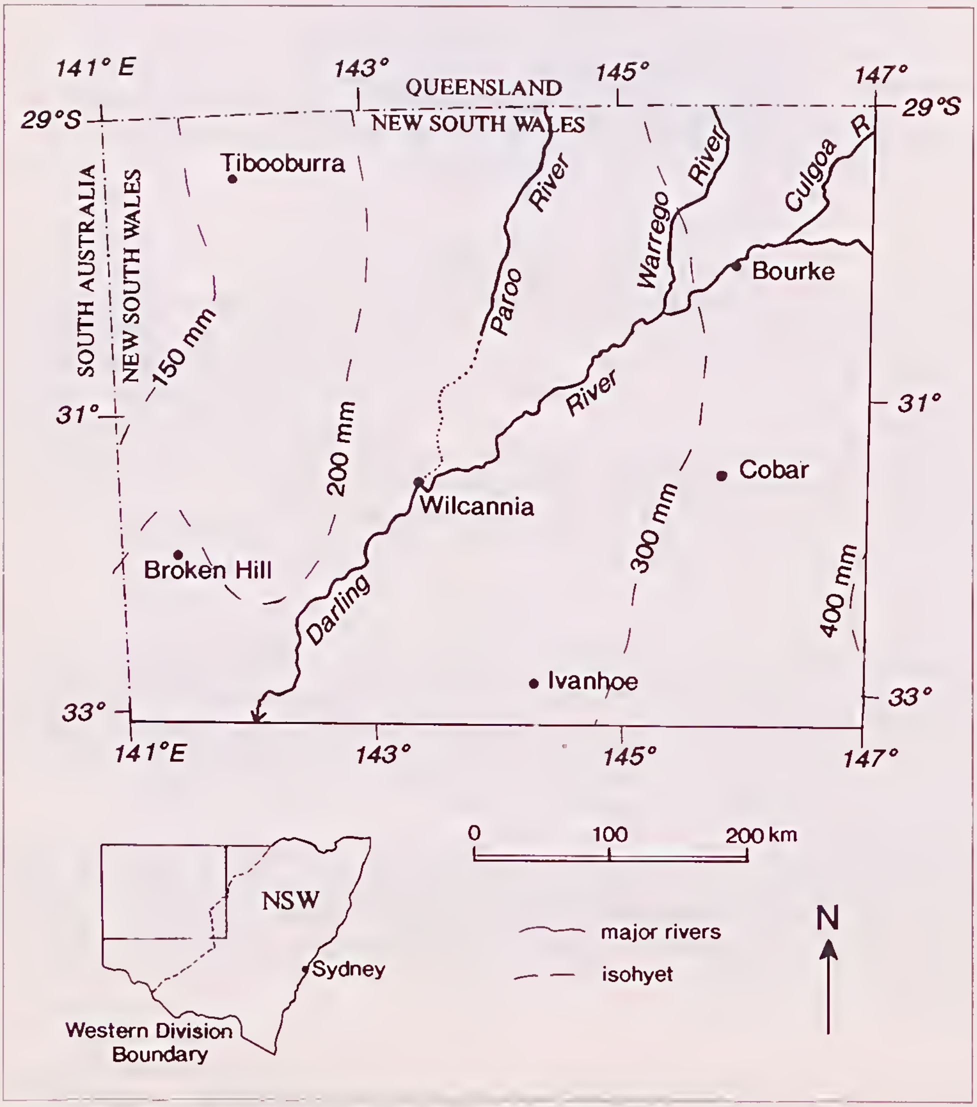


Figure 1. Map area showing main towns, rivers and rainfall isohyets.

Bureau of Statistics 1991). The Shires of Cobar and Bourke have 14% and 10% respectively. Population numbers between towns are very low and widely scattered.

Climate

The map area covers much of semi-arid and arid New South Wales. Long-term mean annual rainfall decreases from east (400 mm) to west (150 mm in the far north-west corner) (Fig. 1), with reliability decreasing from east to west (Fig. 2). Over the long term, rainfall is summer dominant for the northern areas, falling by way of convective storms, and winter dominant in the south associated with cold fronts of lower intensity (Johns, Tongway & Pickup 1984). The north-west corner experiences a fairly even spread of rainfall throughout the year. Variability is greatest in the far north-west corner, but rainfall is highly variable over the whole area and prolonged periods of low rainfall and occasional floods are characteristic.

Rainfall patterns over decades may be recognised, though records for most of the area are barely 100 years old. Despite the massive and well-publicised droughts of the late 1890s (Royal Commission 1901), the period prior to 1910 was generally wetter than from 1911 to 1947 (Gentilli 1971). Since then, rainfall has been substantially higher and with a marked increase in the amount of summer rainfall (Pittock 1981). Within any one of these periods, individual years may be wetter or drier, but the decadal pattern occurs across all of the mapped area.

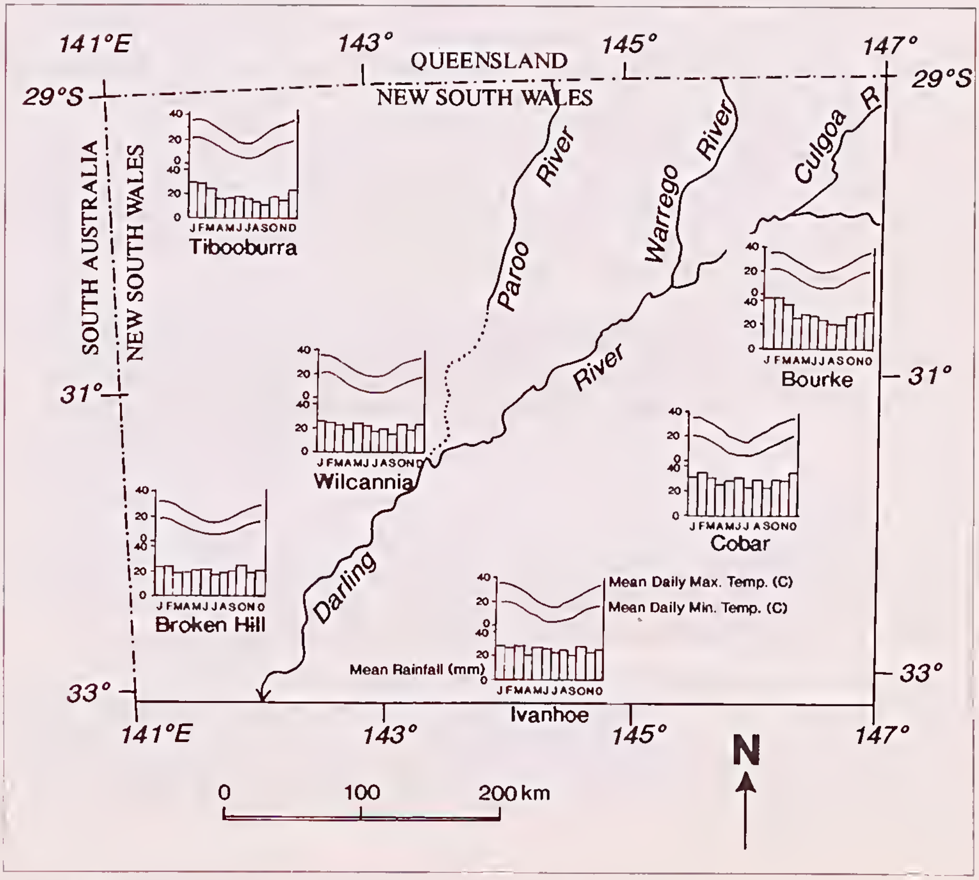


Figure 2. Monthly rainfall and temperature for major centres.

Temperatures are hot in summer and mild in winter. Figure 2 displays long-term mean monthly maximum and minimum temperatures for particular stations within the area. Major departures from maximum temperatures may occur for short periods and are not uncommon, with temperatures exceeding 40° C during December to February and exceeding 35° C during October to March (Bureau of Meteorology 1988). Available data indicate that evaporation increases from south to north and from east to west, being highest in the far north-west corner (Cunningham et al. 1981). In all months mean evaporation exceeds mean rainfall (Dalton 1988).

Frosts are common in many areas; most occur in the period May–June to August–September.

In the late 19th and early 20th centuries, massive dust storms were a common feature of western NSW (Royal Commission 1901). However, more recently, they have been less frequent. From 1957 to 1984, dust storms occurred once per two years to twice per year over most of the map area. In the southern section bordering the extensive mallee of south-western New South Wales, dust storms were more frequent in 1957 to 1984, averaging two to five per year (McTainsh et al. 1989).

Geology

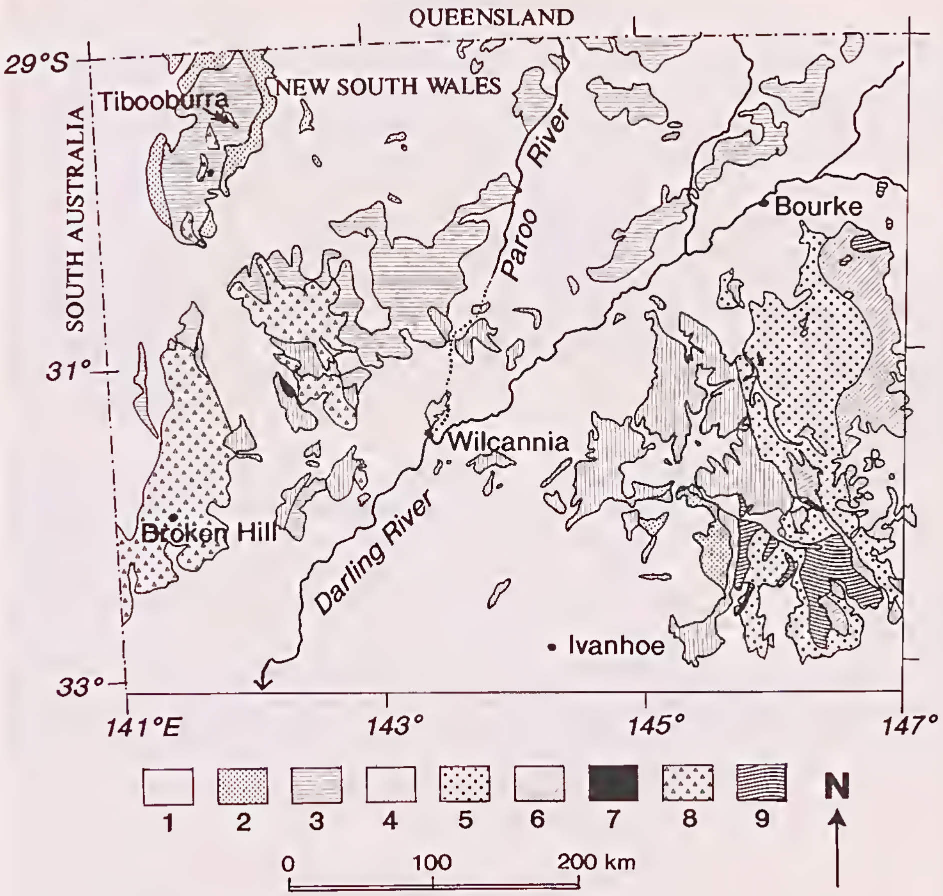
The geology of the map area, summarised in Figure 3, is a complex mosaic of geological units representing rock formations of various ages overlain by more recent sediments.

The North Western Fold Belt comprises the outcrop areas of Broken Hill and the Barrier Range, the ranges in the Mootwingee area and parts of the Grey Range in the Milparinka–Tibooburra area. Most of these outcrops are Pre-Cambrian in age and consist of conglomerate, sandstone, shale, limestone, tillite, schist, gneiss, amphibolite, pegmatites and gabbro (Packham 1969; Geological Survey of NSW 1972; Cunningham et al. 1981). Small areas of Devonian sandstones, quartzites, acid lavas and chert outcrop, as well as Cretaceous sandstones, siltstones and shale. Tertiary sedimentary deposits (silcrete) are common in the Milparinka–Tibooburra area, where the oldest formations of granites, phyllites and schist can be found.

Rocks of the Central and Southern Highland Fold Belt are younger; the oldest comprise Ordovician sandstones, siltstones, chert, quartzite, limestone, tuff, andesite, slate and greywacke. Devonian and Silurian sediments and volcanics are common in the region, as well as Silurian–Devonian granites and granodiorites.

The Great Artesian Basin comprises mainly Quaternary alluvial material along the major river systems, particularly along plains in the Brewarrina district. Quaternary sands of mostly aeolian origin can be found in the western sections of the Basin. North of the Darling River are extensive areas of Cretaceous sandstones, siltstones, claystone and shale; marine shales outcropping in the White Cliffs area are the source of opal. In the deeper parts of the Basin towards the Queensland border more sandy lacustrine beds overlie sandstone and shale sequences.

In the main, the Murray Basin is a Permian–Tertiary sedimentary basin containing thick sequences of Eocene marine sediments. Reworking of the sediments since the Tertiary has resulted in a covering of Quaternary sediments of fluvial and aeolian origin (National Parks & Wildlife Service 1982). Few rock outcrops are present but include the Devonian Manara Hills north-west of Ivanhoe, and the Darnick Range south-west of Darnick.



1: QUATERNARY gravel, sand, silt, clay;

2: TERTIARY conglomerate, sandstone, silstone, claystone, gravel, sand, silt, clay;

3: CRETACEOUS sandstone, silstone, claystone, shale, coal;

4: DEVONIAN conglomerate, sandstone, mudstone, arkose, quartzite, tuff, limestone, chert, acid to basic lavas, porphyry;

5: SILURIAN conglomerate, sandstone, mudstone, quartzite, slate, tuff, limestone, lavas and porphyry;

6: ORDOVICIAN sandstone, siltstone, chert, quartzite, tuff, andesite, slate and greywacke;

7: CAMBRIAN conglomerate, sandstone, shale, limestone, chert, lava;

8: PRECAMBRIAN conglomerate, sandstone, shale, limestone, tillite, schist, gneiss, amphibolite, pegmatite, gabbro;

9: PRECAMBRIAN–IGNEOUS granite, adamellite, granodiorite, porphyry, monzonite, andesite.

Figure 3. General geology of map area (after Packham 1969).

Geomorphology

There are two main landform types in the map area — erosional and depositional. The erosional landforms comprise only a small percentage of the area compared to the predominantly depositional environment, where wind and water have distributed and continue to distribute sediments (Cunningham et al. 1981).

Relief is dominated by the Barrier and Grey Ranges and the mesa country around White Cliffs and Mootwingee. Mt Robe (474m) in the Barrier Range is the highest point west of the Darling River. In the eastern part of the map the most extensive erosional surface is the Cobar Pediplain (Lawrie 1976), with the isolated McCullochs Range east of Wilcannia being the westerly extension of this. Approximately 80 km south of Cobar lie the Tarran Hills (508m) which represent the highest elevation in the Western Division. In other areas relief is provided by smaller ranges and isolated hills such as the Manara Hills north-west of Ivanhoe and Thoolabool Range south-west of Louth.

Much of the map area consists of level to undulating plains 70–250 m above sea level. The north-west corner is characterised by densely spaced linear sand ridges which have formed on the deepest sands. Large areas of scattered linear sand dunes can also be found south-east of Broken Hill (Australian Water Resources Council 1972). Level sand plains are common in more northerly areas (National Parks & Wildlife Service 1982).

A large proportion of the map area is drained by the Darling River through-drainage system and associated rivers. Associated with the Darling River catchment are extensive alluvial floodplains dissected by a complex network of channels and lakes which only carry water during floods. The far north-west corner of the area forms part of the extensive inland channel country where waters flow south-west and drain into Lake Frome in South Australia.

Soils

Details regarding soil types of the map area have been well documented (Stannard 1962; James 1960; Mabbutt 1973; Lawrie 1976, 1991; Cunningham et al. 1981; Soil Conservation Service various dates). Broadly, nine major soil types occur throughout the map area. Lithosols (skeletal soils), brown gibber soils and red earths are associated with areas of relief, red-brown earths and grey and brown clays are associated with alluvial plains, whilst desert loams, solonised brown soils, calcareous red earths and dune sands are associated with the aeolian plains.

History of settlement

Aboriginal occupation

Recent archaeological studies suggest that Aborigines have occupied western New South Wales for at least 40 000 years (Bowler 1971, Allen 1980). During this time the climate, flora and fauna have changed substantially and the distribution of occupation over time is in part due to the availability of food and other resources, in particular fresh water (National Parks & Wildlife Service 1982).

The Aborigines may have largely altered the ecosystems in which they lived by the use of fire to aid their hunting and gathering and through their use of local resources generally. However, unlike the Europeans, it seems likely that the Aborigines had a kinship with the land (Pickard 1990b). From accounts by the early explorers (Mitchell 1838; Sturt 1849), Aboriginal occupation in the recent past seems to have been centred on the major river systems, and the drier country away from permanent water sources was used opportunistically when seasonal or heavy rains permitted hunting in more favoured areas. However, Aborigines overcame the lack of permanent water in the drier areas, since it has been found that occupation on a regular basis away from rivers was quite common (Harris 1989).

European Occupation

After the early exploring expeditions, initial settlement on lands east of the Darling River was slow, due to Government policy aimed at controlling land occupancy within the 19 counties of the 'Limits of Location'. However, squatters gradually spread out onto adjoining lands and the pressure for land settlement was such that in 1836 by Act of Council, it was decided to allow squatters to graze their stock, paying an annual fee of 10 pounds (King 1957). By 1850 the frontages of the Darling River up to Wilcannia had been occupied (National Parks & Wildlife Service 1982). Most of the land east of the River had also been taken up but settlement was limited by lack of permanent water; the land could only be used opportunistically after rains.

Land west of the Darling River was settled later, mainly associated with the more reliable sources of water such as the Darling River and smaller, often ephemeral, supplies along local drainage areas, for example in the Barrier Range (Mabbutt 1973). The discovery of the vast artesian water supply and the subsequent sinking of bores and construction of wells paved the way for a greater settlement in drier areas and by the end of the 19th century the majority of the map area was settled.

Land use

Arid and semi-arid rangelands of western New South Wales have now been grazed for between 110–140 years (Cunningham & Milthorpe 1981, Pickard in press a). During this time there have been various irreversible soil and vegetation changes.

The squatters brought in large numbers of domestic stock. Cattle predominated at first but were later replaced by sheep (Cunningham et al. 1981) with wool production becoming the major industry. Mining assisted in opening up many areas away from permanent water, particularly during the gold boom of the 1850s. Broken Hill and Cobar remain today as viable centres through mining for silver, lead and zinc, whilst opals are mined at Lightning Ridge and White Cliffs.

Currently, the main land use is pastoral with sheep remaining the most numerous domestic animal. Cattle numbers fluctuate in response to price and market availability. Some of the large feral goat population is periodically trapped and sold for meat and for introduction into mohair-producing flocks (Cunningham et al. 1981). Dryland cropping is undertaken during favourable times particularly along the eastern edges of the map area, and on some of the dry lakebeds such as Lake Tandou.

Less than 3% of the map area is conserved in National Parks, Nature Reserves and Historic Sites managed by the National Parks & Wildlife Service. The Forestry Commission of NSW has a Forest Preserve and some Timber Reserves in the eastern section of the map sheet.

Land tenure

Lands to the eastern edge of the map sheet and lying outside the Western Division are mostly held under freehold title. However, most of the map area lies within the Western Division and is predominantly held under leasehold tenure; the bulk of this is held under perpetual lease (Condon 1976). A large proportion of these holdings are held as Western Lands Leases through the Western Lands Act of 1901. Western Lands Leases may be for grazing and agriculture, town residential blocks and business sites (Western Lands Commission 1990). A very few other holdings remain under the Crown Lands Act.

Leasehold land allows restrictions to be placed on the term of the lease as well as some control over land use — for example, control of land use for a specific purpose such as pastoralism, control of the intensity of use (limiting stock numbers), setting conditions for the control of noxious plants and animals, encouraging land improvements, and the right of the Crown to minerals (Western Lands Commission 1990).

Review of vegetation and studies

Charles Sturt during his 1844–46 exploration of the interior of the continent first described the vegetation and collected plant material (Sturt 1849). Cambage (1900a, 1900b) made notes on plant species and habitats in the Bourke to Cobar and Cobar to the Bogan River above Nyngan. Turner (1903, 1905) described plant species of the Darling and north-western New South Wales regions. Haviland (1911, 1913) described species and their habitats from the Cobar country, including a map with place names and localities and MacGillivray (1923) described plant species whilst travelling north through the Barrier and Grey Ranges. Collins (1923, 1924) produced the first detailed discussions on the flora and ecology of the Grey Ranges, discussing predominant vegetation types and habitats, associated species, and annual flora.

Beadle (1948) published the first vegetation map of western NSW and his 1:1 024 000 scale map (1" = 16 miles) and its accompanying memoir have remained the standard reference to the vegetation ever since. Although produced before the advent of air photos and under rather difficult conditions (Beadle 1981a), it is remarkably accurate. The detailed notes of the memoir are mandatory reading for the serious student of the vegetation of western NSW. An interesting account of Beadle's first trip to the west in 1939 is given in Beadle (1981b).

A vegetation map of the Paroo–Upper Darling region was compiled by James (1960) as part of his erosion survey of that region. Stannard (1963) carried out similar work in the central East–Darling region. Morris (1939) discussed plant regeneration at Broken Hill and west Darling region plants (Morris 1966); Milthorpe (1972) and Burrell (1973) described vegetation in the Fowlers Gap–Calindary area north of Broken Hill.

Vegetation studies in adjacent areas include those of Specht (1972) for South Australia and Dawson and Boyland (1974) and Boyland (1974) for Queensland. More recent studies include those of Cunningham et al. (1981), Cunningham & Milthorpe (1981), Beadle (1981a), Soil Conservation Service of NSW (various dates), and include Dalton 1988; Irons & Quinlan 1988; Iwaszkiewicz & Semple 1988), Boyland (1984), Neldner (1984), Fox (1991), Milthorpe (1991), Porteners (1993), Scott (1992), Walker (1991) and Wade (1992). Extensive bibliographies list research papers and publications dealing with a range of subjects relating to the Western Division (Moore 1986; Semple & Irons 1989; Parson 1990, 1991).

Methods

Mapping procedure was based primarily on the reinterpretation of existing 1:250 000 scale geological maps of the area, as a strong relationship between geological type and vegetation type became apparent from early fieldwork. Preliminary maps at 1:250 000 scale were field-checked over many seasons from 1971 to 1978 using extensive ground traverses on most public roads and many station tracks in the area (Fig. 4). This was carried out by Pickard during his employment as plant ecologist with the Royal Botanic Gardens. At this stage, the maps included many vegetation units smaller than 2 km across. These individual maps were photo-reduced to 1:1 000 000 scale and the vegetation was compiled onto a single base map. During this transfer, very small units were omitted, and the boundaries simplified somewhat. Some boundaries needed modification where they crossed borders of the compilation sheets, but this was usually minor. Further field checking followed. Specific areas were also checked using existing Land System maps published by the Soil Conservation Service of NSW, Landsat satellite images, and occasionally, air photos.

Such a procedure is appropriate in large semi-arid and arid areas such as this where maps are to be published at 1: 1 000 000 scale. Beard pioneered this rapid technique in his vegetation maps of Western Australia (e.g. Beard 1974, Beard & Webb 1974). The basis of the technique is that geological maps are prepared by interpreting air

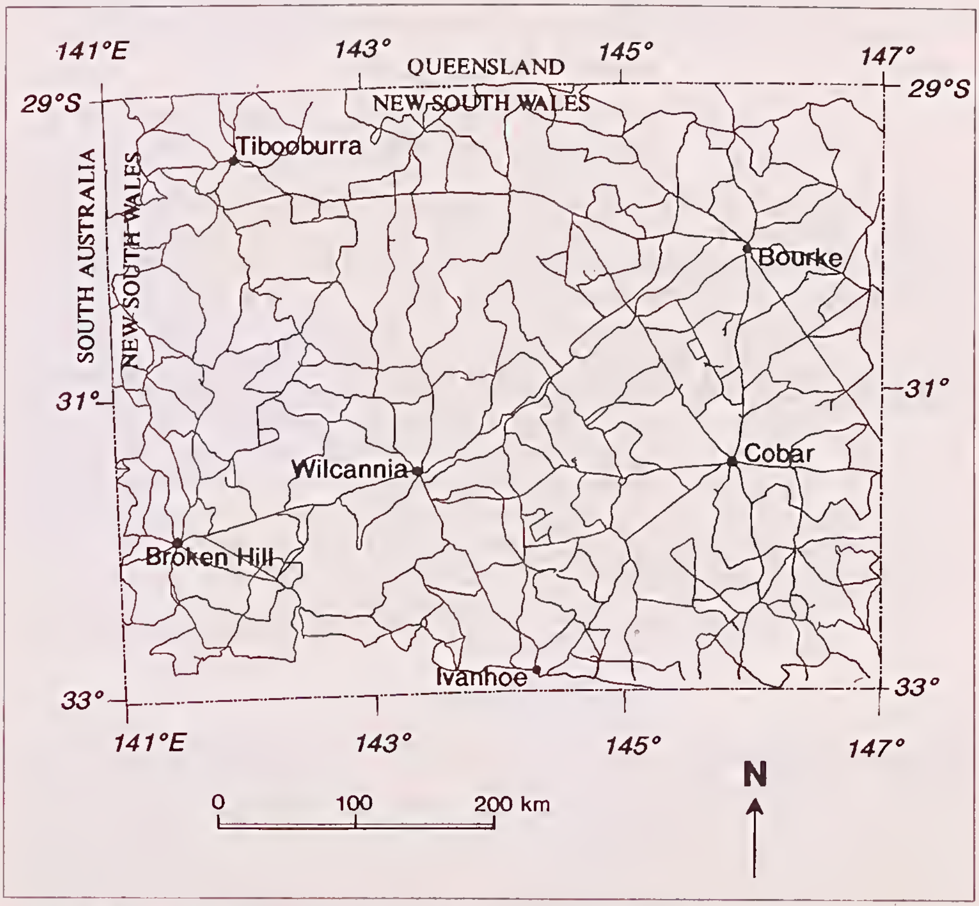


Figure 4. Extent of vehicular traverses of map area during field work.

photo patterns which include vegetation. Despite Beadle's (1948) earlier conclusion, it is clear that one of the primary controls of vegetation in western NSW is geology.

The accuracy of the technique has been compared with that of vegetation maps produced by direct air photo interpretation. Pickard & Boyland (1981) compared a draft of the present map and an adjoining 1:500 000 scale vegetation map in Queensland. The Queensland map was prepared by interpreting stereo pairs of 1:80 000 scale air photos, compiling land systems at 1:250 000 before final vegetation mapping at 1:500 000. There were very few boundaries displaced on the border by more than 5 km, and most of these could be reconciled by slightly expanding the definitions of the vegetation units.

Such adjustments recognise the subjectivity inherent in vegetation mapping (Pickard 1983). Within a single map sheet, the units should be consistently conceived, described and mapped. However, there will be greater or lesser inconsistencies between mappers. This does not present major problems because, as Pickard & Boyland (1981) showed, differences are readily reconciled for continent-wide standardisation.

Draft copies of the map have been widely available over the last decade. However, there has been little feedback on the accuracy of the map. While this may suggest that the users were all satisfied with the map, a more likely explanation is inertia, and the perceived difficulty in writing to report a problem. Publication of the map has been in response to the continuing need for information on the vegetation of western New South Wales and the Western Division. The draft map, prepared by Pickard, has been redrawn and some corrections made by Norris in consultation with Pickard.

Using the map

Cartographic printing limits the smallest area that can be depicted on a map to about 3 mm across. This represents 3 km at the 1: 1 000 000 scale. In other words, the map is unable to resolve or display different communities or variation finer that 3 km. This has important consequences for both preparing and using the map.

Since the smallest unit shown on this map is about 3 mm across, representing 3 km on the ground, any vegetation community, no matter how distinct, that is smaller than this will not be shown. Thus a small rocky hill may support a very distinctive and easily recognised community of *Eucalyptus vicina*. However, because the hill is only 1.5 km across, it is simply not mapped as different from the surrounding *Eucalyptus populnea* subsp. *bimbil* woodland. This does not mean that the map is inaccurate — it simply reflects the limitations of scale inherent in cartography. Therefore, attempts to digitise the map and subsequently enlarge portions to, say 1:250 000 will not improve the accuracy.

Vegetation overview

Although the vegetation cover shown on the map is presented as the pre-settlement distribution, it is largely based on present-day conditions, with extrapolation into areas that have been completely or partially changed. This is to meet the map's purpose as a baseline description for the whole area. The descriptions, however, reflect present-day conditions and concentrate on major perennial species. Regrettably there are little data on the ephemeral component of the vegetation or of the changes that have been incurred because of stock and rabbit grazing. Norris prepared the descriptions of the map units using a range of references, including Pickard's field notes and in consultation with him. References to other sources of information on the vegetation are given where possible. Botanical names follow Harden (1990–1993), though it has not always been possible to determine all subspecies. For example, subspecies of *Alectryon oleifolius* and *Senna artemesioides* are only given where certainly known.

General description

Much of the western area of the map sheet supports small trees of Mulga, *Acacia aneura*, with dense stands occurring between the Darling River and the Cobar–Byrock district. Elsewhere, Mulga forms open-woodlands with its density decreasing westward as aridity increases. To the east and south-east it merges with Bimble Box (also known as Poplar Box), *Eucalyptus populnea* and other woodlands, while to the south with shrublands predominantly of *Atriplex*, *Maireana*, *Casuarina pauper* and Mallee (*Eucalyptus socialis*, *Eucalyptus dumosa*).

Climatic and edaphic factors are the major controls on vegetation growth in the region and these have been discussed elsewhere (Beadle 1948; Cunningham et al. 1981; Eldridge 1988; Milthorpe 1991). Other factors such as topography, fire, flood, drought and management are also important for plant growth and survival.

Plant communities

There are 41 plant communities recognised and mapped (Table 1) and a further 28 mosaic communities also recognised.

Map unit 1

Callitris glaucophylla open-forest

(White Cypress Pine)

Geographic distribution: Generally extends from Queensland to Victoria on sandy areas throughout western New South Wales and also occurs in South Australia, Western Australia and the Northern Territory. In New South Wales communities are widespread, and mapped west of the Noonthorangee Range, north of Mootwingee and north-west and south-west of Cobar. Two other smaller areas are mapped east of Milparinka and east of Menindee.

Landforms: Gently undulating to rolling topography, but not in depressions.

Soils: Predominantly sandy, often infertile with a pH ranging from 5–7.4. On shallow stony soils in the eastern area of its range it is replaced by Black Cypress Pine, *Callitris endlicheri*.

Structure: Where it forms dense stands, *Callitris glaucophylla* suppresses herbaceous ground cover, its own litter forming a thin layer so that the ground is almost free of small plants. It is very fire-sensitive and is susceptible to grazing by stock and rabbits.

Map unit 2

Callitris glaucophylla – Eucalyptus intertexta open-forest

(White Cypress Pine–Red Box)

Geographic distribution: Widespread in the south-eastern corner of the map sheet, and also for a small area east of Byrock.

Landforms: Level to undulating country and low gravelly rises.

Soils: Red-brown clay loams, sandy loams and gravelly soils in elevated positions.

Structure: These communities form extensive open-forests, 20–24 m in height.

Canopy species: *Grevillea striata*, *Brachychiton populneus* and *Acacia excelsa*.

Other species: The understorey is commonly shrubby and includes *Eremophila mitchellii*, *Geijera parviflora*, *Alectryon oleifolius*, *Apophyllum anomalum*, *Senna artemisioides* (various subspp.), *Dodonaea viscosa* subsp. *angustissima* and *Eremophila longifolia*.

The herbaceous layer, although sparse, is dominated by *Aristida jerichoensis* var. *subspinulifera*, *Eragrostis*

Table 1. Plant communities and map units recognised and described for the vegetation map of north-western New South Wales

Open forest	1 *Callitris glaucophylla* 2 *Callitris glaucophylla–Eucalyptus intertexta* 3 *Eucalyptus ochrophloia* 4 *Eucalyptus coolabah* subsp. *coolabah*
Woodland	5 *Eucalyptus populnea* subsp. *bimbil* 6 *Eucalyptus populnea* subsp. *bimbil–Callitris glaucophylla* 7 *Eucalyptus populnea* subsp. *bimbil–Eucalyptus intertexta* 8 *Eucalyptus intertexta–Acacia aneura* 9 *Eucalyptus melanophloia–Triodia mitchellii* var. *breviloba* 10 *Eucalyptus microcarpa* (narrow-leaved race) 11 *Eucalyptus camaldulensis* 12 *Acacia excelsa*
Open woodland	13 *Eucalyptus* aff. *terminalis–Eucalyptus populnea* subsp. *bimbil*
Low open forest	14 *Callitris glaucophylla* 15 *Eucalyptus largiflorens* 16 *Acacia cambagei* 17 *Acacia harpophylla*
Low woodland	18 *Casuarina pauper–Alectryon oleifolius* subsp. *canescens* 19 *Eucalyptus* aff. *terminalis–Atalaya hemiglauca*
Tall shrubland	20 *Eucalyptus socialis* (sandplain) 21 *Eucalyptus socialis* (rocky hills) 22 *Eucalyptus vicina* 23 *Eucalyptus gillii* 24 *Acacia aneura* (sandplain) 25 *Acacia aneura* (rocky hills) 26 *Acacia aneura–Acacia ligulata* 27 *Acacia aneura–Acacia tetragonophylla* 28 *Acacia aneura–Acacia excelsa–Geijera parviflora* 29 *Acacia loderi* 30 *Acacia clivicola*
Shrubland	31 *Acacia ramulosa* 32 *Acacia cana* 33 *Atriplex nummularia*
Dwarf open scrub	34 *Atriplex vesicaria* (downs and ranges) 35 *Atriplex vesicaria* (floodplains) 36 *Maireana pyramidata* 37 *Maireana sedifolia*
Herbland	38 *Eragrostis australasica–Muehlenbeckia florulenta*
Grassland	39 *Astrebla lappacea* (floodplains) 40 *Astrebla* spp. (downs)
Salt lakes	41 Salt lake communities

lacunaria, and *Stipa* spp. Other perennial and annual species may include *Digitaria brownii*, *Enteropogon acicularis*, *Sclerolaena diacantha*, *Chenopodium* spp., *Calotis cuneifolia*, and *Sida cunninghamii*.

Map unit 3

Eucalyptus ochrophloia open-forest

(Yapunyah)

Geographic distribution: Restricted to the Paroo River (and adjacent lower reaches of adjacent Purnanga and Dingo Creeks) and channels of Cuttaburra Creek.

Landforms: Floodplains and associated channels, pans and sandy rises.

Soils: Brown clays, red texture-contrast soils, gravel and stony beds of streams.

Structure: Variable low open-forest to woodland, in essentially monotypic stands (Fig. 5). Variable amounts of *Muehlenbeckia florulenta* and *Eragrostis australasica* forming dense herbland along channels. Some patches of tall shrubs (for example *Acacia stenophylla*).

Canopy species: Generally only *Eucalyptus ochrophloia*, but on fringes a range of other trees: *E. coolabah* subsp. *coolabah–E. coolabah* subsp. *arida* (see notes in Map unit 4), *E. camaldulensis*, *E. populnea* subsp. *bimbil* and *E. largiflorens*.

Other species: A wide range of shrubs occupy slightly lower (wetter) and higher (drier) sites in a bewildering manner: *Maireana aphylla*, *Acacia victoriae*, *A. stenophylla*, *Eremophila bignoniiflora*, *E. polyclada*, *E. maculata*. Herbs include *Muehlenbeckia florulenta*, *Sclerolaena muricata*, and many other annual *Sclerolaena* species and annual *Atriplex* species as well as a number of ephemeral species occurring after floods. Many grass species: *Eragrostis australasica*, *E. setifolia*, *Astrebla lappacea*, *Paspalidium jubiflorum*, *Leptochloa digitata*, *Dichanthium sericeum* and *Digitaria ammophila*.

Merges with: Other northern floodplain communities, especially *Eragrostis australasica–Muehlenbeckia florulenta* herbland, *Eucalyptus populnea* low open-forest, *Maireana pyramidata* low open-shrubland, as well as dryland communities.

Map unit 4

Eucalyptus coolabah subsp. *coolabah* open-forest

(Coolibah)

Geographic distribution: Floodplains of the Darling River and its tributaries upstream of Wilcannia, and especially upstream of Louth.

Landforms: Quaternary alluvium with more recent rises of sandier sediment (small source-bordering dunes), various depressions in the plains.

Soils: Grey cracking clays and grey self-mulching clays

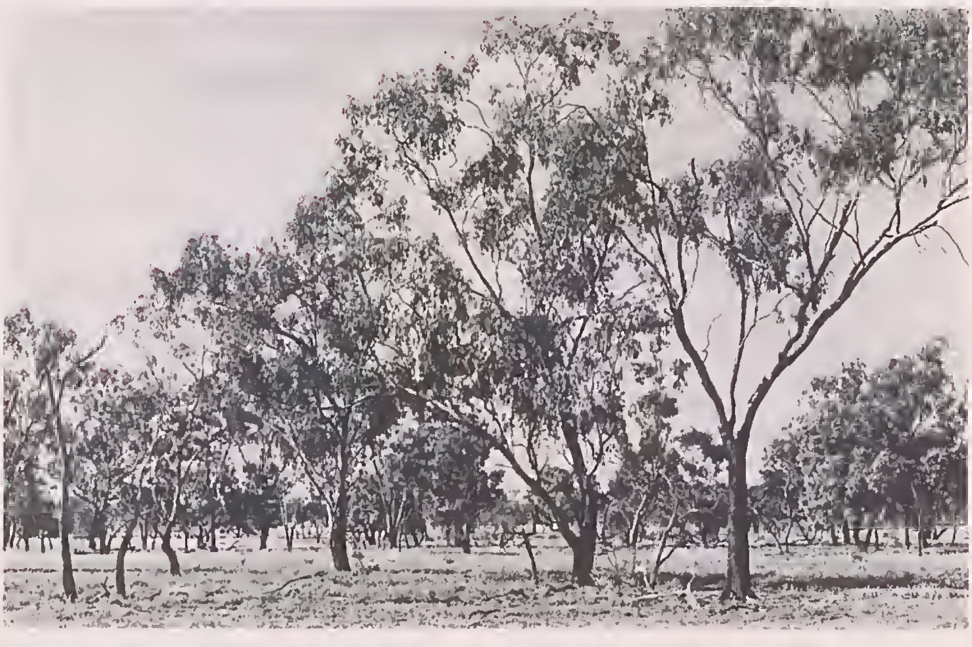


Figure 5. *Eucalyptus ochrophloia* open-forest (Map unit 3). Cuttaburra Creek.

with gilgais and crab-holes, sandy soils on rises.

Structure: As mapped here, the community includes a wide range of structural forms, ranging from open woodland dominated by *E. coolabah* to ephemeral herbland with no single dominant. Shrub layer may be present. The extensive plains are most often essentially treeless, but are mapped here for convenience.

Canopy species: *E. coolabah*, *E. largiflorens*, *E. camaldulensis*, *Casuarina pauper*/*C. cristata*. Two subspecies are recognised in the map area: subsp. *coolabah* is common throughout on heavier soils, while subsp. *arida* is confined to the the far north-western corner, usually in sandy or gravelly creek lines in stony or sandy desert country.

Other species: Shrubs: *Acacia victoriae*, *A. stenophylla*, *Atalaya hemiglauca*, *Eremophila bignoniiflora*, *Atriplex nummularia*, *Chenopodium nitrariaceum*, *Rhagodia spinescens*, dense *Dodonaea viscosa* subsp. *angustissima* on sandy rises. Herbs dominated by various annual chenopods together with a wide range of season-specific ephemerals (including grasses).

Merges with: Other southern floodplain communities (*Eucalyptus camaldulensis* open-forest, *E. largiflorens* low open-forest and *Eragrostis australasica*–*Muehlenbeckia florulenta* herbland and dryland communities (*Maireana pyramidata* (sandplain) low open-shrubland, *Atalaya hemiglauca* open-woodland).

Map unit 5

Eucalyptus populnea subsp. *bimbil* woodland

(Bimble Box or Poplar Box)

Geographic distribution: Communities dominated by Bimble Box form extensive woodlands through parts of the map area, particularly in the eastern areas south of Bourke and around Cobar. Here they occur on plains and gentle slopes, often in seasonal drainage lines. Further west in lower rainfall areas, the community becomes more restricted to drainage lines and near White Cliffs is found essentially as a riparian community only. Some extensive stands occur in closed depressions forming "Bimble Box swamps", which are seasonally inundated. (Beetson et al. 1980.)

Landforms: Extensive slopes and low ridges, floodplains coming off stony downs, from 0.2 to 3 km wide, with incised channels, and various higher sandier patches.

Soils: Variable mixture of unconsolidated creek sediments (clay to silt to gravel), brown clays and texture-contrast soils.

Structure: The structure of Bimble Box communities varies with soil type. On moderately fertile loamy soils and heavy clays a two-layered tree-grass structure predominates. At its maximum development communities on these sites may approach low open-forest to 10 m or more high. On lighter-textured, more sandy soils, there is frequently a variable understorey of shrubs — *Callitris glaucophylla* is often codominant.

Canopy species: Dependent on soil type: red earths support *Acacia excelsa*, *Geijera parviflora* and *Alectryon oleifolius*. Lighter soils also have *Callitris glaucophylla*, heavy clay soils in depressions have *Casuarina cristata* and *Acacia harpophylla*. *Eucalyptus microcarpa* may also be present as an associated species in alluvial and clay soils on plains and gentle slopes in the south-east of the map area.

Other species: Various shrubs including *Acacia victoriae*, *Eremophila longifolia*, *Maireana pyramidata*, *M. aphylla*, *A. tetragonophylla* and *A. aneura*. Frequently invaded by woody weeds, especially *E. sturtii* and *E. mitchellii*. Grasses and forbs are very variable, the main species being *Eragrostis setifolia*, and annual *Sclerolaena* species.

Merges with: Other floodplain communities except *Eucalyptus coolabah* open-woodland; *Maireana pyramidata* low open-shrubland (creeks); low open-woodland and low open-woodland–tall open-shrubland communities dominated by *Casuarina pauper*–*Alectryon oleifolius* and other species. Forms a boundary community between creeks entering the western side of the Paroo River. Forms mosaics with *Callitris glaucophylla* (Map unit 5/1) and *Acacia excelsa* (Map unit 5/12) adjacent to the Paroo River and Cuttaburra Creek.

Map unit 6

Eucalyptus populnea subsp. *bimbil*–*Acacia aneura*–*Acacia* spp. woodland

(Bimble Box–Mulga–Acacia)

Geographic distribution: These communities are widespread on the plains country south of Bourke, and are mapped for this area.

Landforms: Level to undulating plains.

Soils: Deep calcareous to acid loamy to sandy red earths.

Structure: Tree cover varies, ranging from an open structure to quite dense stands.

Canopy species: Associated species include *Acacia excelsa*, *Eucalyptus intertexta*, *E.* aff. *terminalis*, *Eremophila mitchellii*, *Apophyllum anomalum*.

Other species: *Senna artemisioides*, *Dodonaea viscosa* subsp. *angustissima* and *Eremophila sturtii*. Ground covers include *Aristida* spp., *Eragrostis eriopoda*, *Chloris truncata* and other perennial grasses and forbs.

Map unit 7

Eucalyptus populnea subsp. *bimbil*–*E. intertexta* woodland

(Bimble Box–Red Box)

Geographic distribution: These communities form extensive woodlands south-east of Bourke and east and north-east of Cobar.

Landforms: Relatively hilly topography.

Soils: Shallow skeletal soils having a light texture.

Structure: They form predominantly a shrub woodland with understorey species including *Geijera parvifolia*, *Senna artemisioides*, *Alectryon oleifolium* and *Eremophila mitchellii*. Other minor species of less importance include *Apophyllum anomalum*, *Senna artemesioides*, *Dodonaea viscosa* subsp. *angustissima* and *Eremophila longifolia*. Interspersed within these communites is *Eucalyptus viridis* which occurs on more shallow soils and slight rises.

As rain decreases *E. intertexta* becomes more dominant over *E. populnea* subsp. *bimbil*, especially on stony ridges and hills.

These communities sometimes grow in a mosaic with *Callitris glaucophylla* (Map unit 7/1).

Map unit 8

Eucalyptus intertexta–*Acacia aneura* woodland

(Red Box–Mulga)

Geographic distribution: These communities are mapped for a region on the western fringe of the Cobar pediplain north-west of Cobar.

Landforms: Low gravelly rises and ridge crests with sandstone or quartzite rock outcrops. They can also be found in rocky drainage lines.

Soils: Red earths, which may sometimes be quite shallow, and in the more hilly areas soils are skeletal.

Structure: *Acacia aneura* predominate in the intermediate areas between the scattered stands of *Eucalyptus intertexta*, standing 10–15 m in height.

Canopy species: Associated species include *Acacia excelsa*, *Atalaya hemiglauca*, *Geijera parviflora*, *Grevillea striata*, *Alectryon oleifolius* and *Brachychiton populneus*. *Callitris glaucophylla* is almost entirely absent.

Other species: Shrubs may include *Pittosporum phylliraeoides*, *Senna* spp., *Eremophila* spp. (including *E. mitchellii*). The herbaceous layer may include *Aristida jerichoensis* var. *subspinulifera*, *Aristida contorta*, *Eragrostis eriopoda*, *Tripogon loliiformis*, *Monachather paradoxa*, *Thyridolepis mitchelliana*, *Paspalidium constrictum*, *Sclerolaena* spp. and *Sida* spp.

Map unit 9

Eucalyptus melanophloia–*Triodia mitchellii* var. *breviloba* woodland

(Silver-leaved Ironbark–Buck Spinifex)

Geographic distribution: These communities are mapped for two localised areas north-west of Brewarrina. *Eucalyptus melanophloia* is more common in country to the east of the map sheet area.

Landforms: Sandplains and dunefields

Soils: Variable, range from deep sandy red earths to texture-contrast soils with a light clay B-horizon.

Structure: *Eucalyptus melanophloia* grows to a height of 7–10 m and commonly forms savannah woodlands with *Triodia mitchellii* var. *breviloba* (Fig. 6).

Canopy and other species: Associated species occurring within these communities are not common but may include *Acacia murrayana*, *Grevillea albiflora*, *G. juncifolia*, *Micromyrtus ciliata*, and *Keraudrenia integrifolia*. Grasses and forbs may include *Eragrostis eriopoda* and *Calandrinia balonensis*.

Map unit 10

Eucalyptus microcarpa (narrow-leaved race) woodland

(Western Grey Box)

Geographic distribution: *Eucalyptus microcarpa* communities are mapped for a small area around, and east, of Bobadah representing a westerly extension of its more easterly distribution in the State.

Landforms Generally gentle slopes and plains.

Soils: Mainly red earths and red-brown earths.

Structure: Woodland, *E. microcarpa* is a medium-sized tree attaining 20 m in height.

Canopy species: *E. microcarpa* (narrow-leaved race; this species forms an extensive intermediate, with good breeding populations between *E. microcarpa* and *E. pilligaensis*). Associated species include *Callitris glaucophylla*, *Eucalyptus viridis* and *E. populnea* subsp. *bimbil*.

Other species: Shrubs include *Acacia deanei*, *A. oswaldii*, *Hakea leucoptera*, *Pittosporum phylliraeoides* and *Eremophila longifolia*. Perennial pasture species may include *Danthonia caespitosa*, *Aristida jerichoensis* var. *subspinulifera*, *Paspalidium constrictum* and other annuals and perennial forbs.

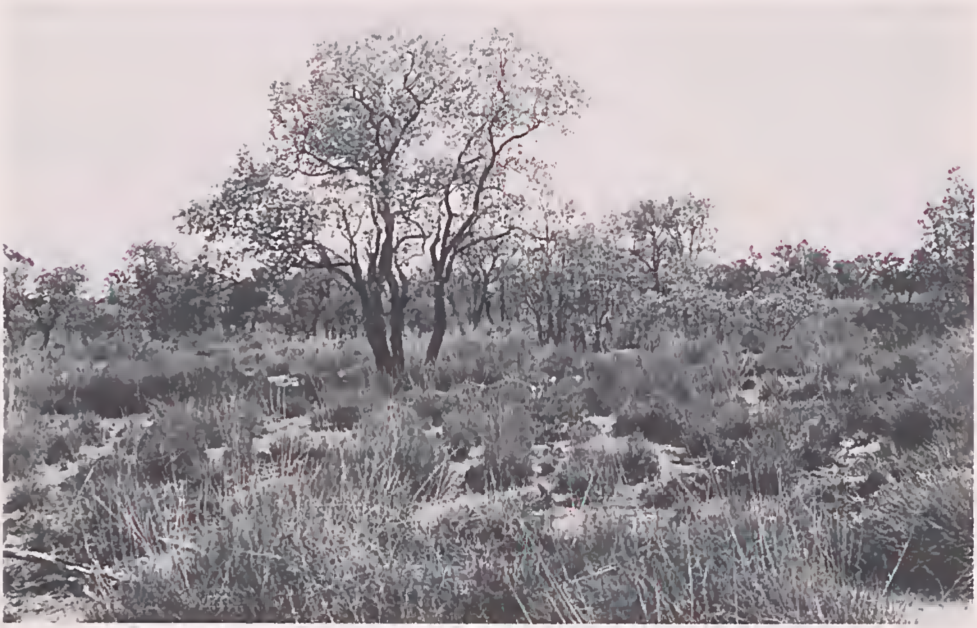


Figure 6. *Eucalyptus melanophloia–Triodia mitchellii* **woodland (Map unit 9).**

Map unit 11

Eucalyptus camaldulensis woodland

(River Red Gum)

Geographic distribution: Along all perennial rivers and large creeks flowing in the map area. Also along major creek channels with intermittent flow.

Landforms: Meandering incised river channels and nearby levee banks; incised channels in ephemeral streams, rocky creek beds.

Soils: Generally grey cracking clays, but also any other soils in creek bottoms.

Structure: At its maximum development along the banks of the major rivers (Darling and Lachlan) this community forms a forest of trees up to 30 m high. More typically, it is an open-forest, and frequently low woodland. There is usually only one tree layer, and occasionally a tall shrub layer of, for example, *Acacia stenophylla* with much shorter *Chenopodium nitrariaceum* or *Rhagodia spinescens*. *Muehlenbeckia florulenta* commonly occurs as dense to open thickets where there are large gaps in the tree canopy.

Where the community occurs in channels on broad creeks, it is usually restricted to the active and not-long inactive channels. Whenever a new channel is formed, it is quickly colonised by a single or double row of *E. camaldulensis*. Whether these ever survive to form open-forest is a function of the stability of the landforms. In Wannara Creek near White Cliffs, channels have migrated > 100 m in the past 100 years (Pickard1994) and all the *E. camaldulensis* in traces of the oldest channels are long dead. Short-lived channels frequently show lines of dying *E. camaldulensis*, e.g. channels of Wannara Creek below "Arrowbar" homestead.

Canopy species: *Eucalyptus camaldulensis*, with variable amounts of *E. populnea* subsp. *bimbil* and *E. coolabah* depending on the site. (*E. camaldulensis* in the Barrier Range to Tibooburra area is a distinct taxon, L.A.S. Johnson pers. comm.)

Other species: *Acacia stenophylla*, *Chenopodium nitrariaceum*, *Rhagodia spinescens*, *Muehlenbeckia florulenta* and a wide range of ephemerals after floods.

Merges with: All other flood plain communities. This community sometimes grows in a mosaic with *Eucalyptus populnea* subsp. *bimbil* (Map unit 5) east of White Cliffs, and *E. largiflorens* (Map unit 15) along the Darling River.

Map unit 12

Acacia excelsa woodland

(Ironwood)

Geographic distribution: *Acacia excelsa* communities are scattered and are mapped for the north-eastern portion around Louth, north of Louth, and north-west to north-east of Bourke.

Landforms: Level to undulating country on well-watered drainage flats, and may also be found on sandplains and sand ridges.

Soils: Variable. In the Bourke district these communities grow on deep sands and are commonly associated with *Callitris glaucophylla*. On solonised brown soils and red earths *A. excelsa* grows with *A. homalophylla*, *A. aneura*, *Eremophila mitchellii*, *Grevillea striata*, *Hakea tephrosperma* and *H. leucoptera*.

Structure/Canopy species: *A. excelsa* can occur in almost pure stands, 10 m high or more, or it may intergrade with other species such as *E. populnea* –*Callitris glaucophylla*, *A. aneura* and *E. intertexta*.

Other species: May include *Pittosporum phylliraeoides*, *Apophyllum anomalum*, *Senna artemisioides*, *Dodonaea viscosa* subsp. *angustissima*, *Olearia pimelioides*. Groundcovers may include *Eragrostis eriopoda*, *Aristida jerichoensis* var. *subspinulifera*, *Dichanthium sericeum*, *Aristida contorta* and *Sclerolaena diacantha*. *Acacia excelsa* is an important drought-fodder species.

Acacia excelsa grows in a mosaic jointly with *Eucalyptus populnea* subsp. *bimbil* (Map unit 5) and *Callitris glaucophylla* (Map unit 1), ie. 12/5/1, having a limited distribution north of Bourke and north and north-east of Enngonia; with *Casuarina cristata*–*Alectryon oleifolius* (Map unit 18) in the Enngonia district; and with *Acacia aneura* (Map unit 24) north-east of Wanaaring and adjacent to the Paroo River and Cuttaburra Creek.

Map unit 13

Eucalyptus aff. *terminalis*–*E. populnea* subsp. *bimbil* open woodland

(Inland Bloodwood–Bimble Box)

Geographic distribution: This uncommon community is mapped for an area north-west of Wanaaring and west of the Paroo River towards the New South Wales–Queensland border in country largely dominated by *Acacia aneura* tall shrubland (Map unit 24).

Landforms: The landscape is characterised by extensive, slightly undulating sandplains.

Soils: Typically light-textured soils such as deep sandy to sandy loam red earths.

Canopy species: Associated species may include *Grevillea striata* and *Hakea ivoryi*.

Other species: Shrub species include *Senna artemisioides* and *Dodonaea* spp. The herbaceous layer may include *Aristida* spp., *Enneapogon avenaceus* and *Thyridolepis mitchelliana*.

Map unit 14

Callitris glaucophylla low open-forest

Geographic distribution: Scattered distribution over the south-eastern corner of the map sheet and adjacent to communities dominated by *Eucalyptus socialis* (Map unit 20), *E. vicina* (Map unit 22) and *Callitris glaucophylla*–*E. intertexta* (Map unit 2).

Landforms: Rocky hills and ranges. Here, *Callitris glaucophylla* grows well up the slopes.

Soils: Sandy to loamy lithosols which become deeper and better developed downslope.

Canopy species: *Callitris glaucophylla* (Fig. 7); associated species may include *Acacia doratoxylon*, *Eucalyptus intertexta*, *E. populnea* subsp. *bimbil*, *Myoporum mitchellii* and *Brachychiton populneus*.

Other species: Shrub species may include *Acacia decora*, *Senna artemisioides*, and scattered *Pandorea pandorana*. The herbaceous layer may be dominated by *Stipa* spp., *Aristida* spp., *Amphipogon caricinus* and other grasses and forbs.

Map unit 15

Eucalyptus largiflorens low open-forest

(Black Box)

Geographic distribution: Widespread as a fringing community along creeks, around lakes and in depressions of various sizes from Tibooburra to White Cliffs and along the Darling River floodplain downstream of Wilcannia. Immediately upstream of Wilcannia both *Eucalyptus largiflorens* and *E. coolabah* subsp. *coolabah* may occur but on different sites. Futher upstream, *E. coolabah* open-forest (Map unit 4) predominates.

Landforms: Intermittently flowing billabongs and anabranches adjacent to Darling River; floodplains generally, seasonally flooded internal drainage basins.

Soils: Variable; grey cracking clays with and without extensive areas of crabholes, some texture-contrast soils.

Structure: Extremely variable. At its maximum development an open-forest but more generally low open-forest and even open-woodland. Trees are typically bent, and often occur as a single line around the contour of a previous high flood line. Various shrubs (especially *Chenopodium nitrariaceum* and *Acacia stenophylla*) and herbs occur forming discontinuous lower layers.

Forms complex mixtures with *Eragrostis australasica*–*Muehlenbeckia florulenta* herbland on floodplains of Paroo River, and with *Eucalyptus coolabah* on the floodplains of the Darling River.

Canopy species: *E. largiflorens*, *E. populnea* subsp. *bimbil*, *E. coolabah*, *Casuarina pauper*, *Grevillea striata*.

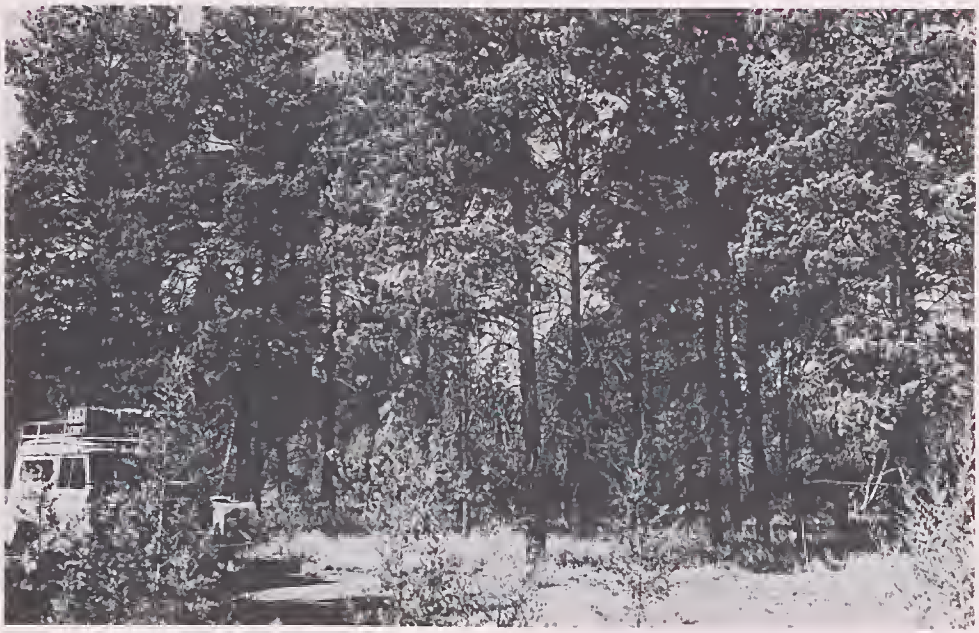


Figure 7. *Callitris glaucophylla* **low open-forest (Map unit 14). Approximately 40 km north-west of Condobolin (32° 47′ S 146° 59′ E).**

Other species: Dense to open stands of *Muehlenbeckia florulenta*, *Acacia stenophylla*, *Chenopodium nitrariaceum*, various *Sclerolaena* species and a range of grasses (e.g. *Eragrostis setifolia*, *Sporobolus mitchellii* and *Eragrostis australasica*). Slightly higher areas on sandier soils with annual *Sclerolaena* and *Atriplex* species, and *Enneapogon avenaceus* under *Myoporum montanum* and *Dodonaea viscosa* subsp. *angustissima*. Some *Acacia victoriae*.

Merges with: All other floodplain communities; and with communities of sandplains. Sometimes forms a mosaic with *Acacia aneura* tall shrubland (Map unit 24), *Atriplex vesicaria* shrubland (Map unit 35), and *Eragrostis australasica*–*Muehlenbeckia florulenta* (Map unit 38) where there is a mix of suitable soils and landforms.

Map unit 16

Acacia cambagei low open-forest

(Gidgee)

Geographic distribution: Large areas between the Paroo and Culgoa Rivers, north of Louth and Bourke, and replaces Brigalow, *Acacia harpophylla* as rainfall decreases to below 550 mm per year.

Landforms: Areas subjected to irregular flooding, such as along the edges of watercourses and drainage channels.

Soils: Variable, include brown and reddish-brown clays and duplex soils on the floodplains, and desert loams along creeks.

Structure: *Acacia cambagei* characteristically forms pure stands to 10 m in height with dense interlacing canopies, or can occur in more open formations.

Canopy species: *Acacia harpophylla*, *Casuarina pauper*, *Apophyllum anomalum*, *Eremophila mitchellii*, *Flindersia maculosa*, *Acacia aneura*, *Atalaya hemiglauca*, *Grevillea striata* and *Alectryon oleifolius*.

Other species: Shrub species may include *Atriplex nummularia*, *Rhagodia spinescens*, *Enchylaena tomentosa* and *Maireana pyramidata*. Herbaceous species may include *Paspalidium jubiflorum*, *Enteropogon acicularis*, *Digitaria* spp., *Eulalia aurea*, *Leptochloa digitata* and *Dichanthium sericeum*. Annual *Atriplex* spp. and *Sclerolaena* spp. may also be present.

The flowers and damp leaves of *Acacia cambagei* give off an offensive more-or-less faecal odour.

Merges with: Floodplain communities, and *Acacia excelsa*, *A. aneura* and *A. harpophylla* communities.

Acacia cambagei sometimes grows in a mosaic with *Eucalyptus populnea* subsp. *bimbil*–*Callitris glaucophylla* (Map units 5 and 1), *Eucalyptus camaldulensis* (Map unit 11), and *Casuarina pauper*–*Alectryon oleifolius* subsp. *canescens* (Map unit 18).

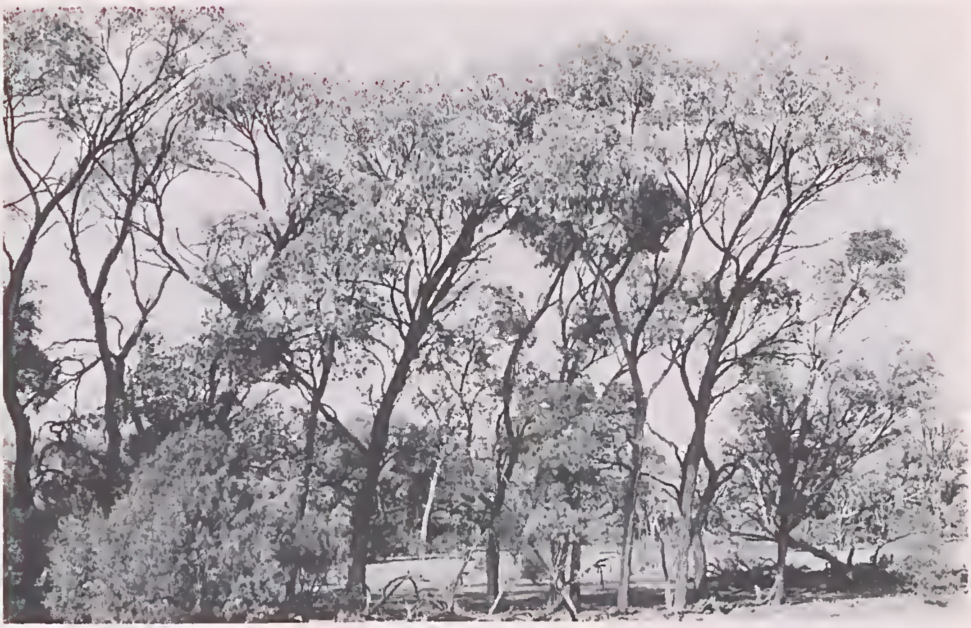


Figure 8. Low open-forest of Brigalow, *Acacia harpophylla* (Map unit 17) (29° 08′ S 146° 33′ E).

Map unit 17

Acacia harpophylla low open-forest

(Brigalow)

Geographic distribution: Scattered occurrences of *Acacia harpophylla* communities are mapped for three localities north-east of Bourke.

Landforms: The landscape is of low-relief sandplains and sandhills. Rarely found on hills and ridges.

Soils: Soils are predominantly red clays, often with gilgai development, alluvial clays subject to flooding, and red earths with sandy clay loam topsoils.

Structure: *Acacia harpophylla* suckers easily from roots and often forms dense monospecific stands to 10–15 m in height (Fig. 8). For detailed descriptions of the structure and floristics see Isbell (1962), Pulsford (1984), Bailey (1984), Johnson (1984) and Wade (1992).

Canopy species: *Acacia harpophylla* can grow in association with *A. cambagei* and *Casuarina cristata*, and occasionally with *Callitris glaucophylla* and *A. pendula*.

Other species: The understorey usually comprises few, if any, shrubs, but may include *Dodonaea viscosa* subsp. *angustissima* and *Eremophila longifolia*. The sparse groundcover may comprise *Atriplex* spp., *Sclerolaena* spp., *Stipa* spp. and *Eragrostis eriopoda* and other grasses and forbs.

Merges with: *Acacia cambagei* and *A. excelsa* communities.

Map unit 18

Casuarina pauper–Alectryon oleifolius subsp. *canescens* low woodland

(Belah–Rosewood)

Geographic distribution: Extensive communites over a wide area of the centre of the map from Broken Hill to west of Bourke, especially south of the Darling River towards Ivanhoe. (Some intergradation of *Casuarina pauper* with *C. cristata* occurs in the area from Bourke to west of Condobolin. *C. pauper* occurs through far western New South Wales, whilst *C. cristata* occurs further east).

Landforms: Generally on undulating sandplains with low relief.

Soils: Calcareous red earths and red earths.

Structure: Varies from parkland with clumps of open-woodland separated by very open areas, to dense scrubs and woodlands, and open forests with trees only 4–5 m apart. Consequently density of trees is highly site specific (Fig 9).

Canopy species: *Casuarina pauper*, *Alectryon oleifolius*, *Flindersia maculosa*, *Acacia aneura*. Pure stands of both dominants are common. Reynolds (1985) recognises two subspecies of *Alectryon oleifolius* in the map area. Subspecies *canescens* usually grows on sand dunes, sandy ridges and hills in the west. Subspecies *elongatus* is more common in open forests, usually on heavy soils, in the east of the mapped area.

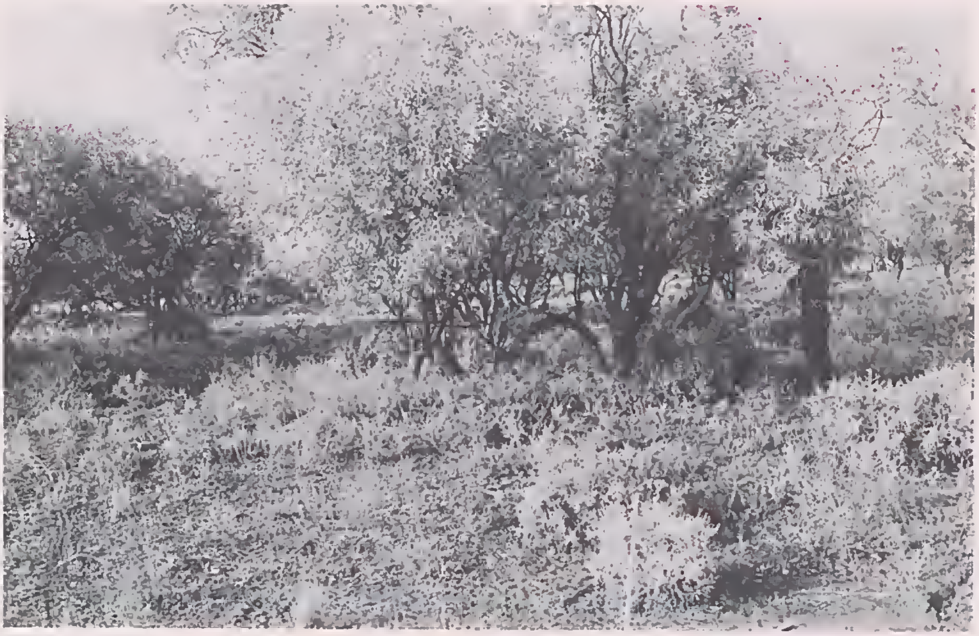


Figure 9. Belah–Rosewood, *Casuarina pauper–Alectryon oleifolius* subsp. *canescens* low woodland (Map unit 18) (32° 19′ S 143° 30′ E).

A major variant of this community occurs in the Wilcannia–White Cliffs area. Here *Casuarina pauper–Alectryon oleifolius* subsp. *canescens–Flindersia maculosa–Acacia aneura* low open-woodland–tall open-shrubland occurs on two distinct site types: loam and gibbers, and sand plain and dunes. The former is restricted to hillslopes and plateaus formed on Cretaceous sediments, and adjacent downslope areas with desert loams and skeletal lithosols, generally with gibbers at surface. The latter occurs on low relief undulating sandplains, with and without extensive areas of sand dunes and swales with calcareous red earths, red sandy earths and deep sands.

The structure of both communities is extremely variable and changes rapidly over short distances from woodland (generally in parkland mosaic of denser and more open phases) to tall open-shrubland. On the hilly gibber sites there is frequently an extensive understorey of *Maireana pyramidata* and/or *Atriplex vesicaria*. The sandy sites now often support dense stands of "woody weeds".

Other species: Dense stands of *Eremophila sturtii* and *Dodonaea viscosa* subsp. *angustissima* (both "woody weeds"), *Apophyllum anomalum*, and some invasion by *Senna artemisioides*, *Acacia cana*, *Maireana pyramidata*, *Atriplex vesicaria*, *Eremophila serrulata*, *E. longifolia*, *Rhagodia spinescens*, *Acacia tetragonophylla*. Grasses include extensive areas of *Astrebla lappacea* on clayey sites, but on sandier sites *Eragrostis setifolia*, *Stipa nitida* and *Enneapogon avenaceus* are more common. *Eragrostis setifolia* is particularly abundant in run-on areas. *Stipa nitida* is particularly obvious after winter rainfall. Herbs are variable and are generally dominated by *Sclerolaena* spp., and various ephemerals.

Merges with: All other communities of gibber slopes and Cretaceous hills, and sandplains; especially *Acacia aneura* tall shrubland, *Maireana pyramidata* shrubland, *Atriplex vesicaria* shrubland, *Eucalyptus socialis* tall shrubland.

This community sometimes grows in a mosaic with *Acacia excelsa* (Map unit 12), *A. aneura* (Map unit 24), and with *Atriplex vesicaria* (Map unit 34).

Map unit 19

Eucalyptus aff. *terminalis–Atalaya hemiglauca* low woodland

(Inland Bloodwood–Whitewood)

This community is mapped for a small area south of Tibooburra. Reaching 6 m in height, the community is commonly found on crests, low rises and stony ridges. The soils comprise gravelly red loams to sandy soils. *Eucalyptus* aff. *terminalis* is to be named *Corymbia tumescens* (L.A.S. Johnson, pers. comm.).

Map unit 20

Eucalyptus socialis tall shrubland

(Red Mallee on sandplain)

Geographic distribution: Extensive areas in south of map area, east of Roto, but extending north to Cobar and west to Wilcannia. Isolated stands are known from north of Bourke and Wilcannia.

Landforms: Gently undulating sandplain.

Soils: Calcareous red earths, with abundant calcareous nodules close to surface.

Structure: Typically a shrubland of mallee individuals from 1.5–5 m tall depending on time since the last wildfire (Fig. 10). Plants have multiple stems arising from an underground lignotuber. Some stands are commonly described as "bull mallee": very large individuals with only a few stems, but each of these up to 10 m high, forming woodland. This is typical of mallee stands which have not been burnt for many years. Wildfire kills the above-ground stems, but new stems sprout from the lignotuber. Smaller shrubs vary locally from few to very abundant. For detailed descriptions of the structure and floristics of mallee vegetation see Hill (1989), Noble (1982, 1984), and Noble et *al.* (1990).

Canopy species: *Eucalyptus socialis*, *E. dumosa*.

Other species: A very wide range of small shrubs, and herbs. The most abundant are *Melaleuca uncinata*, *Olearia* spp., *Alectryon oleifolius* and various grasses, especially *Triodia scariosa*.

Merges with: *Casuarina pauper–Alectryon oleifolius* low open-woodland, *Maireana pyramidata* low open-shrubland.

This community sometimes grows in a mosaic with *Casuarina pauper–Alectryon oleifolius* subsp. *canescens* (Map unit 18).

Map unit 21

Eucalyptus socialis tall shrubland

(Red Mallee on rocky hills)

Geographic distribution: Scattered occurrences south and south-east of Cobar.

Landforms: These communities of *Eucalyptus socialis* occur on stony rises, low ridges and rocky hills.

Soils: Usually shallow loamy to gravelly soils.

Structure: Typical mallee shrubland 1.5–5 m tall.

Canopy species: *Eucalyptus socialis;* Associated species may include *E. populnea* subsp. *bimbil*, *E. intertexta*, *E. viridis;* and *Casuarina pauper–Alectryon oleifolius* and *Acacia aneura* communities.

Other species: The generally sparse understorey includes *Enchylaena tomentosa*, *Sclerolaena* spp., *Atriplex* spp., and other annual and perennial forbs and grasses.

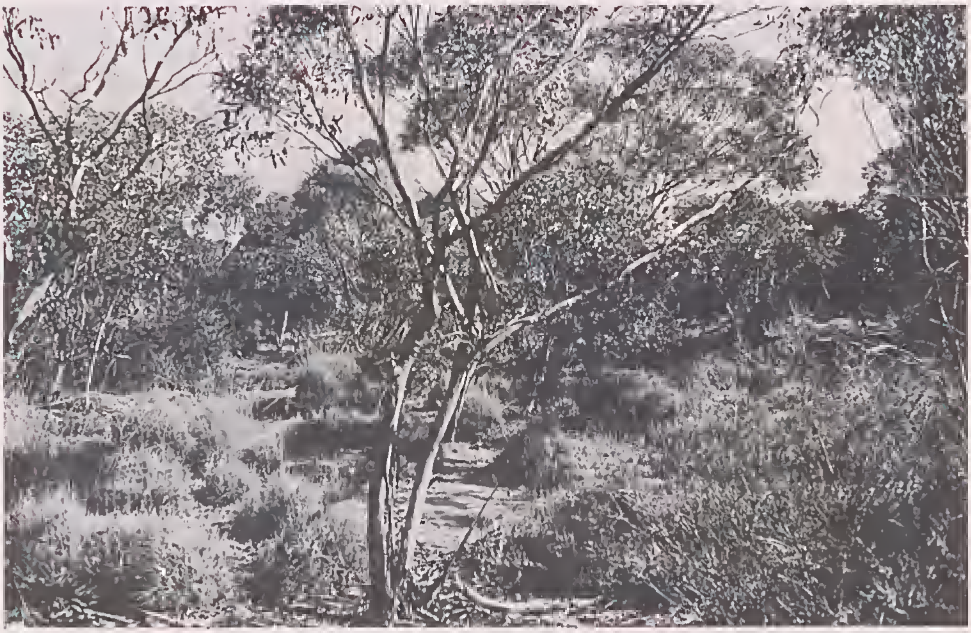


Figure 10. *Eucalyptus socialis* **tall shrubland (Map unit 20). Approximately 35 km south-east of Mt Hope (32° 57′ S 146° 08′ E).**

Map unit 22

Eucalyptus vicina tall shrubland

Geographic distribution: Country around Mt Hope, the Tarran Hills, Mootwingee and the hilly areas north-west of Ivanhoe.

Landforms: Ridge tops and ridge slopes.

Soils: Skeletal well-drained soils overlying sandstone, granite, quartzite or shale.

Structure: Moderate to open tall shrubland, usually found as the dominant species ocurring with *Eucalyptus sideroxylon* and *Callitris glaucophylla*. In many cases the understorey is an open to dense scrub of *Acacia doratoxylon*, although it does form open stands devoid of shrub species.

Canopy species: *Eucalyptus vicina*, *E. morrisii*, *Eucalyptus sideroxylon*, *Callitris glaucophylla*.

Other species: When shrubs are present in the understorey, species of *Prostanthera*, *Cassinia* and *Eriostemon* are common. Ground covers of *Helichrysum bracteatum* and species of *Wahlenbergia*, *Thyridolepis*, *Danthonia* and *Stipa* are usually present.

Map unit 23

Eucalyptus gillii tall shrubland

(Curly Mallee)

Geographic distribution: Main occurrence is in the Flinders Ranges in South Australia, but occurs in disjunct outliers in the northern sections of the Barrier Range, north of Broken Hill.

Landforms: Mainly in rocky terrain of weathered limestone or highly calcareous sandstone.

Soils: Calcareous skeletal, usually red-stained sandy soils.

Structure: Sparsely to moderately spaced trees in small clumps, 3–4 m high surrounded by *Acacia aneura* or forming continuous stands.

Canopy species: Associated species may include *Myoporum platycarpum* and *Eremophila alternifolia*.

Other species: Shrubs include *Maireana pyramidata*, *M. sedifolia* and *Atriplex vesicaria*. Ground covers include *Sclerolaena obliquicuspis* and *Zygophyllum apiculatum* beneath the canopy area, whilst the intercanopy area can be dominated by *Stipa nitida*, *S. trichophylla*, *Sclerolaena* spp. annual chenopods including *Osteocarpum acropterum*, *Atriplex angulata* and *A. lindleyi*. Annual grasses can also be found. Ground cover is rarely abundant after good rains.

Map unit 24

Acacia aneura tall shrubland

(Mulga on sandplain)

Geographic distribution: Extensive areas west of the Darling River and north of Wilcannia, extending to the borders (see also Sattler 1986).

Landforms: Undulating sand plain with some dunefields (especially on western side of Peery Lake and channels of Paroo River).

Soils: Calcareous red earths and deep red dune sands.

Structure: Individual stands vary from dense scrubs to open-woodlands but more typically the community forms tall shrubland of *Acacia aneura*. In the Wilcannia region there are extensive areas of dead *A. aneura*. These are currently being investigated. Many of the dead individuals have been dead for many decades. The cause of such widespread death seems to be a combination of wildfire and perhaps stress from a drought acting on old individuals in a single cohort. In marked contrast, Mulga communities near Bourke are often extremely dense with abundant regeneration and no areas of dead individuals.

Locally on deep sand adjacent to the Peery Hills east of White Cliffs a variant community dominated by *Grevillea striata* and *Eucalyptus intertexta* occurs. This open-woodland is of variable height and density, sometines with a dense shrub layer over a good cover of perennial grasses.

Canopy species: *Acacia aneura*, *Casuarina pauper*, *A. ligulata*, *Alectryon oleifolius* and *Flindersia maculosa*.

Other species: Shrubs: *Senna artemisioides*, *Eremophila sturtii*, *Dodonaea viscosa* subsp. *angustissima* (all three are "woody weeds"), *Myoporum montanum*, *Eremophila longifolia*, *Acacia ligulata*, *A. victoriae*, *Alectryon oleifolius*, *Maireana pyramidata*, *Rhagodia spinescens*, *Eremophila longifolia*. Grasses and forbs: *Aristida jerichoensis*, *A.contorta*, *Eragrostis eriopoda*, *Enneapogon avenaceus*, *Sclerolaena* spp. with *Themeda australis* and *Cymbopogon ambigua* in small creek lines.

Merges with: Other sandplain communities in the south: *Casuarina pauper–Flindersia maculosa–Alectryon oleifolius–Acacia aneura* low open-woodland–tall open shrubland. This community sometimes grows in a mosaic with *Eucalyptus populnea* subsp. *bimbil* (Map unit 5), *E. largiflorens* (Map unit 15), *Acacia cambagei* (Map unit 16), and *Eragrostis australasica–Muehlenbeckia florulenta* (Map unit 38).

Map unit 25

Acacia aneura tall shrubland

(Mulga on rocky hills)

Geographic distribution: Extensive distribution on hills and ranges over a wide area west of the Darling River around the Paroo River and Cuttaburra Creek.

Landforms: Plateaus, scarps and mesas on Cretaceous sediments.

Soils: Lithosols and desert loams, frequently with abundant gibber lag.

Structure: Moderate to open stands of *A. aneura* with extensive open areas of grassland and low open shrubland.

Canopy species: *Acacia aneura*, *Casuarina pauper*, *Flindersia maculosa*, *Atalaya hemiglauca*. On some sites the community becomes almost monotypic *A. hemiglauca* woodland.

Other species: The most common associated species are *Acacia tetragonophylla*, *Eremophila duttonii*, *E. latrobei*, *Prostanthera striatiflora*, *Ptilotus* spp., *Dodonaea viscosa* subsp. *angustissima*, *Maireana pyramidata*, *M. tomentosa*, *Pittosporum phylliraeoides*, *Senna artemisioides*, *E. sturtii*, *Apophyllum anomalum*, *Enneapogon avenaceus*, *Atriplex* spp., and *Sclerolaena* spp. Locally there are stands of *Acacia clivicola* and *A. brachystachya* on tops of scarps and mesas. Herbs include *Ergrostis parviflora* and other chenopods. Grasses are variable: *Astrebla lappacea*, *Enneapogon avenaceus*, *Aristida* spp., and *Thyriodolepis mitchelliana*.

Merges with: *Astrebla lappacea* grassland on plateaus; on slopes with *Maireana pyramidata* low open-shrubland and *Casuarina pauper–Flindersia maculosa–Alectryon oleifolius–Acacia aneura* low open-woodland–tall open-shrubland.

Map unit 26

Acacia aneura–Acacia ligulata tall shrubland

(Mulga–Sandhill Wattle)

Geographic distribution: This community occupies a relatively large area in the far north-west of the map sheet.

Landforms: Predominates on the deep sands of the sand ridges or dune crests replacing *Acacia aneura* (Map unit 24) on the adjacent sandplain country to the east.

Soils: Usually deep neutral to alkaline sands or cemented calcareous sands.

Structure: Tree cover comprises scattered *Acacia aneura* and isolated or clumped *A. ligulata*.

Canopy species: Associated species may include *Hakea leucoptera*, *H. tephrosperma*, *Alectryon oleifolius*, *Casuarina pauper* and *Grevillea stenobotrya*.

Other species: Associated shrubs may include *Senna artemisioides*, *Dodonaea viscosa* subsp. *angustissima* and *Eremophila sturtii*. The ground storey is sparse, and variable depending on whether the soil surface is stable or unstable. Where soils are stable species may include *Enneapogon avenaceus*, *Dactyloctenium radulans*, *Aristida contorta*, *Triraphis mollis*, *Dissocarpus paradoxa*, *Sclerolaena bicornis*, *S. diacantha*, *Helipterum floribundum*, and *Ptilotus polystachyus* var. *polystachyus*. Where soils are unstable species may include *Ptilotus polystachyus* var. *polystachyus*, *Trachymene glaucifolia*, *Eriachne aristidea*, *Eragrostis dielsii* var. *dielsii*, *Salsola kali* (mostly var. *strobilifera*), *Convolvulus erubescens*, *Calotis erinacea* and *Myriocephalus stuartii*.

Merges with: This community sometimes grows in a mosaic with *Eragrostis australasica–Muehlenbeckia florulenta* (Map unit 38).

Map unit 27

Acacia aneura–Acacia tetragonophylla tall shrubland

(Mulga–Dead Finish)

Geographic distribution: Widespread and scattered community on rocky hills and ridges, such as the Barrier Ranges, where it is most common and extensive, the Grey Range, Scopes Range east of Broken Hill and mesas east of White Cliffs. Also occurs on both sides of the Darling River north-west of Wilcannia, and on parts of the Cobar pediplain.

Landforms: Steep to moderate slopes on hills of Devonian sandstone, rocky cliffs, abundant outcropping sandstone.

Soils: Skeletal lithosols, some desert loams. Local patches of aeolian sediment.

Structure: Open-shrubland of rather small and stunted bushes of *Acacia aneura* and *A. tetragonophylla* with extensive open areas. Also extensive areas of dead shrubs. Cause of death may be wildfire or stress from droughts.

Canopy species: *Acacia aneura*, *Atalaya hemiglauca*, *Casuarina pauper*, *Acacia tetragonophylla*, *Grevillea striata*.

Other species: Various herbs including *Ptilotus* spp., and grasses, especially *Enneapogon avenaceus* and *Aristida contorta*.

Merges with: All communities at base of the hills, especially where sediment has accumulated on slopes of hills.

Map unit 28

Acacia aneura–A. excelsa–Geijera parviflora tall shrubland

(Mulga–Ironwood–Wilga)

Geographic distribution: Extensive areas of the Cobar Pediplain and surrounds.

Soils: Sandy to loamy skeletal soils.

Canopy species: *Acacia aneura*, *A. excelsa*, *Geijera parviflora*.

Merges with: Interspersed with *Eucalyptus populnea* subsp. *bimbil* woodland (Map unit 5) and *Callitris glaucophylla* open-forest (Map unit 1), and forms an indistinct boundary on its eastern range with *E. populnea–E. intertexta* woodland (Map unit 7).

Map unit 29

Acacia loderi tall shrubland

(Nelia)

Geographic distribution: Extensive stands between Broken Hill and Wilcannia, but isolated stands beyond (Fig. 11). In 240–280 mm rainfall zone.

Landforms: Undulating sandplain with minor drainage channels, low relief.

Soils: Calcareous red earths.

Structure: Open-shrubland of individual shrubs to small tree, usually with several major trunks arising close to ground.

Canopy species: *Acacia loderi*, *Casuarina pauper*, *Flindersia maculosa*. Over much of its distribution there is relatively little regeneration of *A. loderi*. This may be due to a combination of grazing by stock and death of young individuals by wildfire. Large old individuals are particularly susceptible to killing by fire. Litter of bark, twigs, branches and wind-blown plant material accumulated at the base of the plants burns during fires, killing the plants even though the canopy is barely scorched.

Other species: *Acacia aneura*, *Maireana pyramidata*, *Eremophila sturtii*, various grasses, especially *Stipa* ssp.

Merges with: Surrounding community of *Casuarina pauper–Alectryon oleifolius* open-woodland.

Map unit 30

Acacia clivicola tall shrubland

(Bastard Mulga)

Geographic distribution: Cootaurundee Range west of White Cliffs, and various mesas in the Warwick Hills east of White Cliffs.

Landforms: In the White Cliffs area it occurs on the crest of sandstone ranges and mesas and on plateaus of Cretaceous sediments, stony surface with considerable outcrop of bedrock (Fig 12). On the Queensland border it occurs on extensive sandplains.

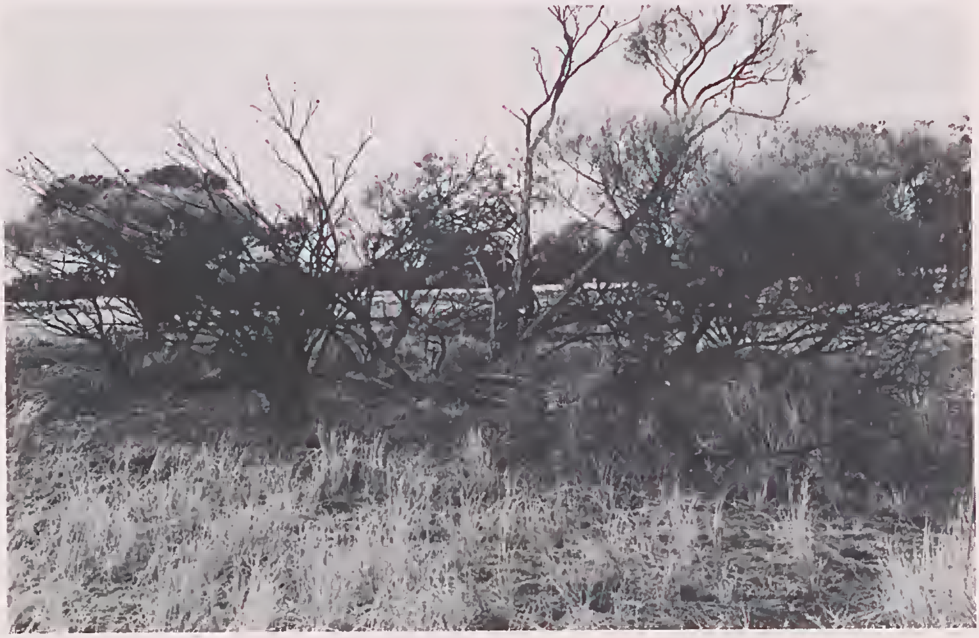


Figure 11. *Acacia loderi* tall shrubland (Map unit 29). Approximately 120 km north of Ivanhoe (32° 08′ S 144° 08′ E).

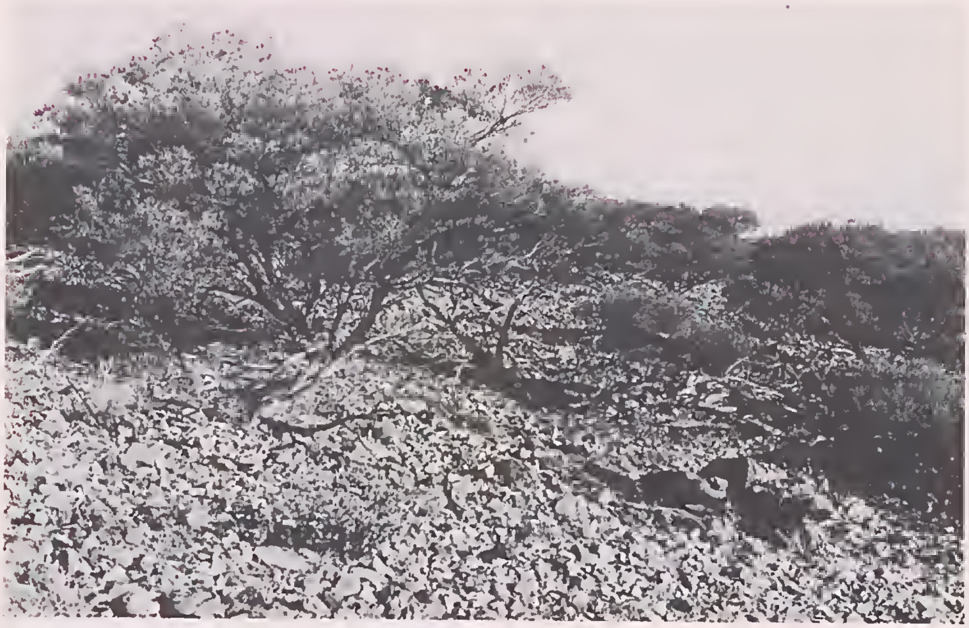


Figure 12. *Acacia clivicola* **tall shrubland (Map unit 30). Crest of Cootaurundee Range, 12 km east of Wertago (30° 56′ S 142° 37′ E).**

Soils: Skeletal lithosols, and red sandy loams.

Structure: Variable shrubland of low and twisted, often multistemmed shrubs. Variable understorey of shrubs and herbs.

Canopy species: *Acacia clivicola*, *A. aneura*, *A. ramulosa*.

Other species: *Maireana pyramidata* and various grasses *Aristida* spp., *Thyridolepis mitchelliana* and *Digitaria* spp. Forbs include *Sida* spp. and *Abutilon* spp.

Merges with: All adjacent communities in these ranges, and on the sandplains.

Map unit 31

Acacia ramulosa shrubland

(Horse Mulga)

Geographic distribution: Ranges and hills west of Brewarrina, and especially west of Wilcannia.

Landforms: Rounded hills, particularly with exposed bedrock of Devonian sandstone, gentle slopes. Also on sand dunes.

Soils: Shallow lithosols, calcareous red earths.

Structure: Typical shrubland of multistemmed shrubs, very bushy and spreading individuals, occasional emergent small trees, variable understorey of low shrubs and herbs (Fig 13).

Canopy species: *Acacia ramulosa*, *A. aneura*, *A. brachystachya*, *Casuarina pauper*, *Flindersia maculosa*.

Other species: *Maireana pyramidata*, various other perennial chenopods.

Merges with: Adjacent communities, especially *Acacia aneura–A. tetragonophylla* open-shrubland, *Casuarina pauper–Alectryon oleifolius* open-woodland. *Acacia ramulosa* Shrubland is often found on small rocky hills within *Eucalyptus populnea* subsp. *bimbil*, *Eucalyptus intertexta* and *Acacia aneura* communities.

Map unit 32

Acacia cana shrubland

(Cabbage-tree Wattle)

Geographic distribution: Communities are scattered and are mapped for the north-west of the region, particularly in the White Cliffs area.

Landforms: Broad sandy watercourse areas and adjacent low rises.

Soils: Red earths or brown gibber soils on creek floodplains, and hardsetting, scalded red soils, and lighter-textured soils on rises.

Structure: Shrubland to 4 m forming dense pure stands or widely scattered trees.

Canopy species: *Acacia aneura*, *Flindersia maculosa*, *Casuarina pauper*, and *Alectryon oleifolius*. *Acacia cana* sometimes replaces *A. cambagei* along shallow watercourses.

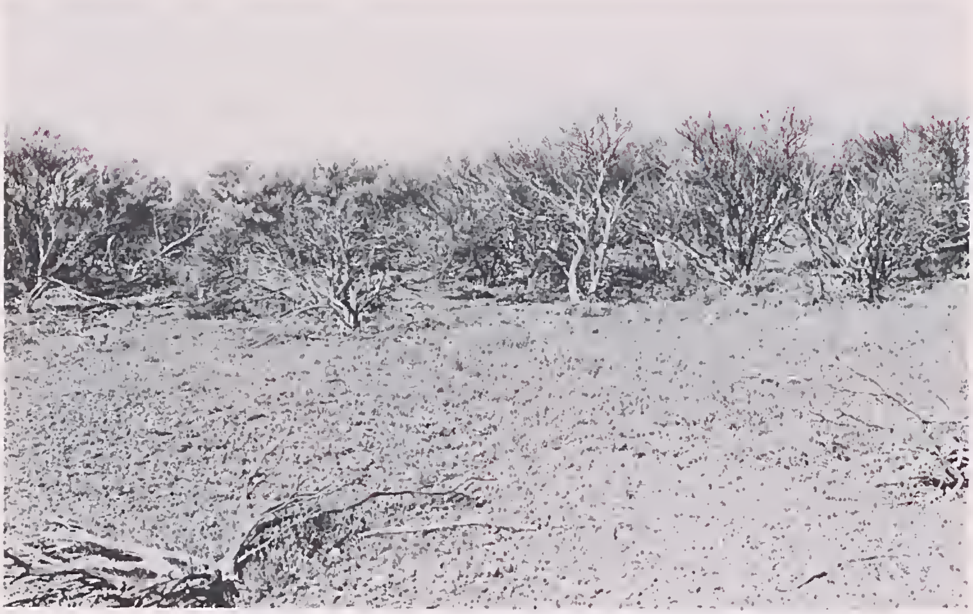


Figure 13. ***Acacia ramulosa*** **shrubland (Map unit 31). The Dolo Hills, approximately 80 km west of Wilcannia (31° 43′ S 142° 43′ E).**

Other species: Shrub species within these communities include *Eremophila sturtii*, *E. maculata*, *Dodonaea viscosa* subsp. *angustissima*, and *Senna* spp. Ground covers may include *Chloris truncata*, *Eragrostis dielsii*, *E. parviflora*, *Triraphis mollis*, and *Dactyloctenium radulans*, and species of *Atriplex* and *Sclerolaena*.

Map unit 33

Atriplex nummularia shrubland

(Old Man Saltbush)

Geographic distribution: Floodplain of Darling River close to junction with Paroo River, and in southernmost sections of Paroo River; north of Clifton Bore in the Bulloo Overflow.

Landforms: Alluvial plains, periodically flooded; sandy rises adjacent to floodplains.

Soils: Grey clays and texture contrast soils.

Structure: Open-shrubland to shrubland up to 2.5 m high with variable grass and forb layer after floods. Some anecdotal evidence suggests that many of the *Atriplex nummularia* communities in the map area are the results of natural spread from deliberate plantings in suitable habitats. However, some survey plans from the 1880s near Wilcanna have the annotation 'Giant Saltbush', indicating that *A. nummularia* was present at the time (Fig. 14).

Atriplex nummularia occurs as an understorey in *Eucalyptus coolabah*, *E. largiflorens* and *Acacia pendula* communities. Formerly it formed extensive stands in *A. pendula* but these have now been destroyed. It also forms localised stands along drainage lines and in depressions throughout *Atriplex vesicaria* shrublands.

Canopy species: *Atriplex nummularia*, *Eragrostis australasica*, *Muehlenbeckia florulenta*, *Chenopodium nitrariaceum*.

Other species: *Sclerolaena muricata*, annual *Atriplex* spp., various ephemerals.

Merges with: *Eragrostis australasica–Muehlenbeckia florulenta* Herbland, *Eucalyptus coolabah* open-woodland.

Map unit 34

Atriplex vesicaria dwarf open-scrub

(Bladder Saltbush on downs and ranges)

Geographic distribution: Widespread in the north-west of map area from Wilcannia to both South Australian and Queensland borders.

Landforms: Broad undulating stony plains, often on plateaus, and on stony ranges.

Soils: Brown desert loams with extensive lags of silcrete gibbers, gilgai brown clays; skeletal lithosols.

Structure: Moderate to sparse *Atriplex vesicaria* forming dwarf open-scrub with open inter-bush areas. On strongly gilgaied sites, *Astrebla lappacea* and various herbs usually occur in the depression and *Atriplex vesicaria* on the rises. On rocky ranges, the inter-bush areas are frequently occupied by various herbs and low shrubs.

Canopy species: Vary with the site and habitat. Downs often have *Atriplex vesicaria*, *Maireana pyramidata* (especially in sandier soils in drainage lines), and *Astrebla lappacea*. Ranges and rocky sites often have *Atripex vesicaria*, *Maireana pyramidata* with scattered emergent *Acacia aneura* and *Casuarina pauper*. Low open woodland of *Acacia cana* on sandier rises and in creeks.

Other species: Wide range of herbs and grasses, especially *Astrebla lappacea*. In some areas, scattered *Sarcostemma australe* and *Sclerostegia* spp. occur. Ground cover species on downs are usually short-lived perennial grasses, especially *Enneapogon* spp., *Triraphis mollis*, *Sporobolus actinocladus*, *Dichanthium sericeum*, and the more long-lived perennial *Eragrostis setifolia*. Common forbs include *Sclerolaena brachyptera*, *S. eriantha* and *S. ventricosa*.

Merges with: *Astrebla lappacea* grassland, communities dominated by combinations of *Acacia aneura* and *Casuarina pauper* on gibber uplands; communites dominated by *Acacia aneura* on ranges.

Map unit 35

Atriplex vesicaria dwarf open-scrub

(Bladder Saltbush on floodplains)

Geographic distribution: Widespread in the north and north-east of the mapped area, for example in floodplains of the Darling and Bogan Rivers, and Cuttaburra Creek.

Landforms: Floodplains and low-lying areas.

Soils: Typically grey and brown cracking clays, and shallow-surfaced-red brown earths.

Structure: Moderate *Atriplex vesicaria* forming a dwarf open-scrub (Fig. 15).

Canopy species: *Maireana pyramidata*, *Maireana aphylla* and *Nitraria billardieri* may be present and *Atriplex nummularia* may also form localised patches. These communities are mainly treeless but may have a tree cover of *Eucalyptus coolabah* subsp. *coolabah* or *Acacia pendula*.

Other species: Between *Atriplex vesicaria* bushes are forbs and grasses of varying quantity depending on the season.

Atriplex vesicaria shrubland sometimes grows in a mosaic with *Astrebla lappacea* (Map unit 39) and after a series of years of summer-dominated rainfall, *Astrebla lappacea* can become more prominent.

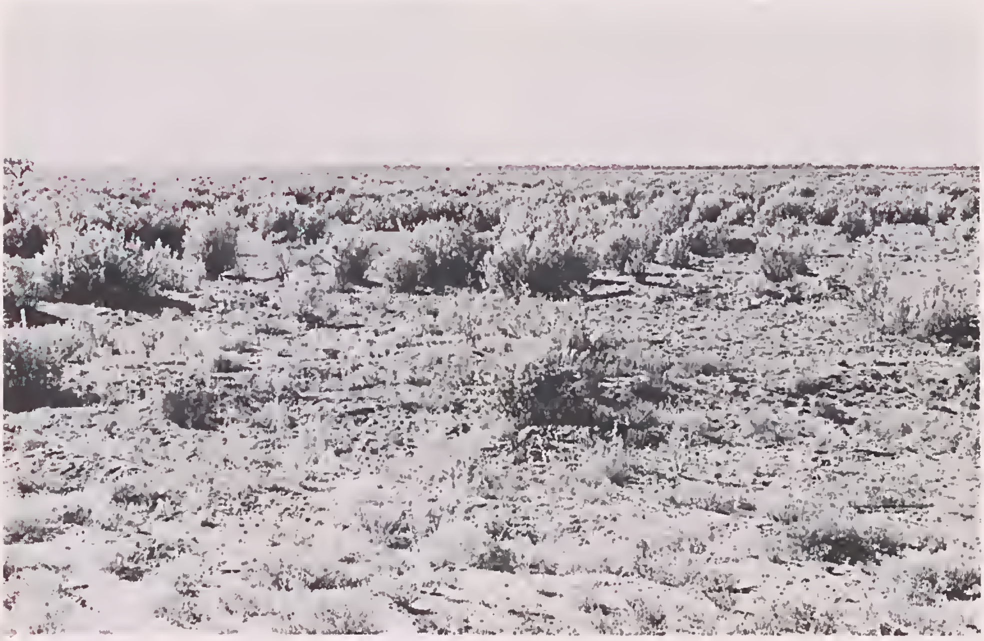


Figure 14. *Atriplex nummularia* **shrubland (Map unit 33). Near Wilcannia (31° 35′ S 143° 23′ E).**

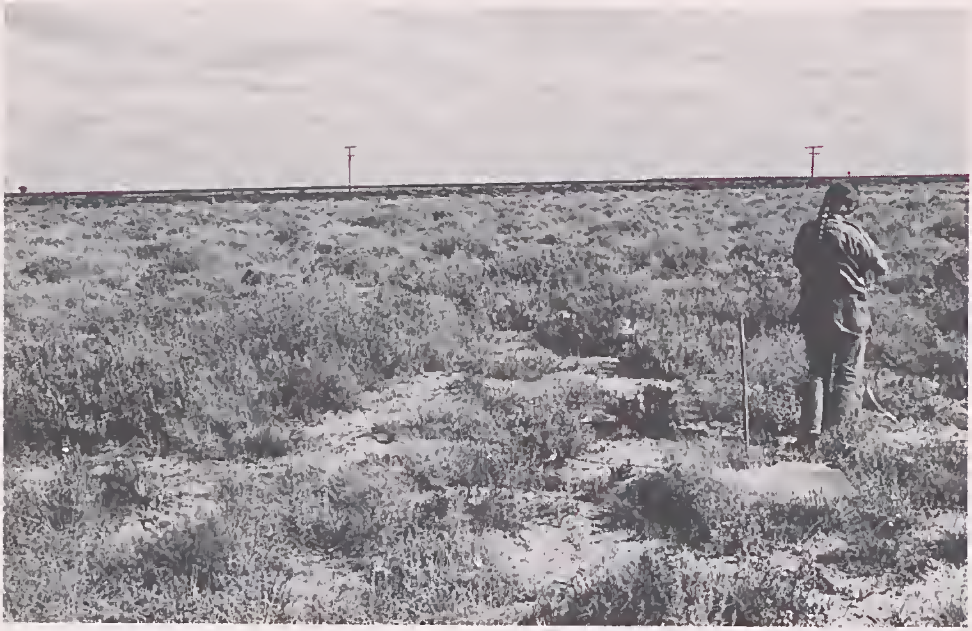


Figure 15. ***Atriplex vesicaria*** **dwarf open-scrub (Map unit 35). Between Conoble and Trida.**

Map unit 36

Maireana pyramidata dwarf open-scrub

(Black Bluebush on sandy loam texture contrast soils)

Geographic distribution: Widespread in the Broken Hill–Wilcannia–White Cliffs area.

Landform: Extensive undulating sandplains with aeolian reworking and usually with a texture contrast, higher areas on floodplains of Darling River. Also on broad sandy creeks and lower stony slopes of rises.

Soils: Texture-contrast soils, red desert loams in creeks and on edges of rises.

Structure: Dense to sparse and extensive areas of *Maireana pyramidata*. Locally there may be numerous small bushes which indicate post-World War II establishment of new plants. There may be emergent small trees, and invasion by "woody weeds" forming dense thickets.

Canopy species: *Maireana pyramidata*, emergents include *Casuarina pauper*, *Atalaya hemiglauca*, *Acacia aneura* and *Flindersia maculosa*. *M. astrotricha* is commonly mixed with *M. pyramidata* and becomes more common on shallower soils. *M. aphylla* may be locally co-dominant, especially in broad drainage lines.

Other species: Shrubs: *Senna artemisioides*, *Dodonaea viscosa* subsp. *angustissima*, *Eremophila sturtii*. Locally *Acacia victoriae* may be abundant. Locally there may be extensive invasion by *Lycium ferocissimum* and *Solanum glaucum*.

Interbush areas support a variety of forbs and grasses. Forbs: *Sclerolaena* spp., *Brachycome* spp., *Calotis* spp., *Helichrysum* spp., *Helipterum* spp. and *Medicago* spp. Grasses: *Stipa nitida*, *Enneapogon avenaceus*, *Eragrostis setifolia*, *Danthonia caespitosa*, *Aristida* spp., *Vulpia* spp., and *Bromus* spp. Annual species of *Atriplex* and *Sclerolaena* (especially *S. muricata*), *Eragrostis parviflora*.

Merges with: Other communities of sandplains (especially *Casuarina pauper*–*Alectryon oleifolius*) and *Atriplex vesicaria* on more clayey soils.

Map unit 37

Maireana pyramidata dwarf open-scrub

(Blackbush on loams and gibbers)

Geographic distribution: In the Barrier Ranges north of Broken Hill, and in the Noonthorangee Range west of White Cliffs.

Landforms: Rocky rises and ridges, extensive undulating plains of gibbers, adjoining slopes and associated broad drainage lines.

Soils: Self-mulching brown clays and red desert loams usually highly calcareous, often skeletal lithosols.

Structure: Dense to sparse low shrubs to 1.5 m high, frequently with emergent small trees.

Canopy species: *Maireana pyramidata*, *M. astrotricha* (especially near rock outcrops), *Atriplex vesicaria* ssp. *calcicola*, emergent *Casuarina pauper* and *Flindersia maculosa*.

Other species: *Astrebla lappacea*, and various annual *Sclerolaena* spp.

Merges with: Adjoining *Astrebla lappacea* grassland, and communities dominated by combinations of *Casuarina pauper* and *Flindersia maculosa* on gibber plains and slopes.

Map unit 38

Eragrostis australasica–Muehlenbeckia florulenta herbland

(Canegrass–Lignum)

Geographic distribution: Widespread across entire map area, always associated with drainage lines and depressions: for example, these areas include and are mapped for the Bulloo River overflow country, extensive areas along the Paroo River and associated tributaries, scattered occurrences south of Wilcannia and isolated patches near the Warrego River.

Landforms: Seasonally flooded alluvial plains with associated channels and depressions, seasonally flooded run-on areas and internally draining basins within sandplains.

Soils: Grey clays, sometimes self-mulching.

Structure: Dense to open herbland to 3 m tall, but often only 1 m tall. Height depends partially on flood frequency and also on previous management. May be emergent small trees and shrubs.

Eragrostis australasica forms dense almost impenetrable tussock grasslands to 2 m high. Plants are frequently partially submerged with water. During long droughts, the plants gradually die, becoming grey in colour and leaving persistent culms. Individuals of *Muehlenbeckia florulenta*, Lignum, grow 2–3 m tall, but are often much smaller. They form more or less globular, tangled bushes which may be isolated or contiguous. In the latter case, they may form almost impenetrable thickets.

Canopy species: *Eragrostis australasica*, *Muehlenbeckia florulenta*, *Atriplex nummularia*. Emergents *E. largiflorens*, *A. stenophylla*, and *E. ochrophloia*.

Other species: Various shrubs including *Eremophila bignoniiflora*, *Acacia salicina*, *Chenopodium nitrariaceum*, *C. auricomum*, and *Atriplex nummularia*. The rare grasses *Uranthoecium truncatum* and *Eriochloa australiensis* grow in pans with Canegrass–Lignum herbland when the pans are full of water.

Ground cover is normally dependent on the length of time since the depression held water. Various herbs colonise the depressions following the receding water: *Sclerolaena* spp., annual *Atriplex* spp., *Osteocarpum acropterum* var. *acropterum* and the fern *Marseilia drummondii*. Other herbs include *Centipida cunninghamii*, *Minuria cunninghamii*, *Agrostis avenaceua*, *Gnaphalium luteo-album*, *Eragrostis setifolia*, *Verbena supina*, *Sclerolaena muricata* and *Diplachne fusca*. The sedges *Eleocharis pallens* and *Schoenoplectus validus* are common.

Although the dominants require regular flooding, inundation for long periods will kill *Meuhlenbeckia florulenta* and convert the community into one of annual and ephemeral herbs until the next cohort of Lignum assumes dominance. In one example on the Paroo Overflow, Lignum was killed in the 1976 flood and has still not recolonised the plain.

Merges with: All communities bordering drainage lines and depressions on gentle slopes.

Map unit 39

Astrebla lappacea grassland

(Curly Mitchell Grass on floodplains)

Geographic distribution: These perennial grassland communities are widespread along the floodplains of the northern Darling River and tributaries.

Landforms: Low-lying areas subject to periodic flooding.

Soils: Grey clay soils.

Structure/main species: *Astrebla lappacea* forms dense often monospecific stands of tussock grass to 90 cm tall with an upright tufted habit (Fig. 16). It suffers from severe disturbance such as fire, drastic overgrazing and trampling. The seeds were used by Aborigines, who ground them to produce an edible paste. Mitchell grasses are important components of native grasslands and provide drought reserves for grazing.

Other species: These communities may be interspersed with *Atriplex vesicaria–Maireana pyramidata* communities and occasionally with *Acacia victoriae*. *Maireana aphylla* and *Chenopodium auricomum* may also be present. The communities are usually treeless, although they may intergrade with *Eucalyptus largiflorens* and *E. coolabah* subsp. *coolabah* communities.

Ground cover species include *Eragrostis setifolia*, *Dichanthium sericeum*, *Iseilema membranaceum*, *Aristida anthoxanthoides*, *Chloris truncata*, *Sclerolaena biflora*, *Sclerolaena divaricata*, *Helipterum uniflorum* and *Swainsona phacoides*.

This community sometimes grows in a mosaic with *Atriplex vesicaria* (Map unit 35). After a series of years of summer-dominated rainfall, the Mitchell Grass can become more prominent.

Map unit 40

Astrebla grassland

(Mitchell Grass on downs)

Geographic distribution: Discontinuous areas from north of White Cliffs to Tibooburra.

Landforms: Extensive stony and alluvial plains, low slopes, some gilgai areas.

Soils: Soils are typically red-brown sandy loams of the stony downs country. Some self-mulching brown clays.

Structure: Tussock grassland with marked seasonal variation. Considerable spatial variation on patterned ground of gilgais and associated rises.

Canopy species: *Astrebla pectinata* is the most common species, whilst *A. lappacea*, *A. elymoides* and *A. squarrosa* also occur but in decreasing order of abundance. Emergent *Maireana aphylla*, *M. pyramidata* and *Atriplex vesicaria* can occur.

Other species: Very wide range of ephemeral and annual species occurring after seasonal rain, especially *Sclerolaena* spp. After a series of summer-dominant rainfall years the Mitchell Grass predominates, but after a series of winter-dominant rainfall years chenopods may predominate. During the chenopod phase, *Atriplex* species such as *A. angulata*, *A. leptocarpa*, *A. conduplicata* and *A. lindleyi* become more obvious together with *Sclerolaena* spp. and *Osteocarpum* spp. (S. Jacobs pers. comm.)

Merges with: Other communities occurring on low angle slopes of gibber soils.

Map unit 41

Salt lakes

Geographic distribution: Discontinuously north and west from Cobar.

Landforms: Large and small lakes which retain water for long periods when filled, e.g. > 12–15 months (Fig. 17).

Soils: Varies from saline clays, which are often puffy as a result of high salt levels, to cracking clays with extensive crabholes.

Structure: The bases of depressions are generally bare. The margins have extremely variable communities depending on salinity, slope and period since last inundation. These are mainly seasonal herbland strand communities that follow the receding water line.

Canopy species: Extremely variable.

Other species: Characteristic species include *Heliotropium curassavicum*, *Mimulus repens*, *Morgania floribunda*, *Bergia ammanioides*, *Glinus ammannioides* and *Swainsona* spp. Some saline areas may have perennial shrubs of *Halosarcia* spp. and *Sclerostegia* spp. (S. Jacobs pers. comm.).

Merges with: *Eragrostis australasica–Muehlenbeckia florulenta* herbland and other communities of alluvial plains.

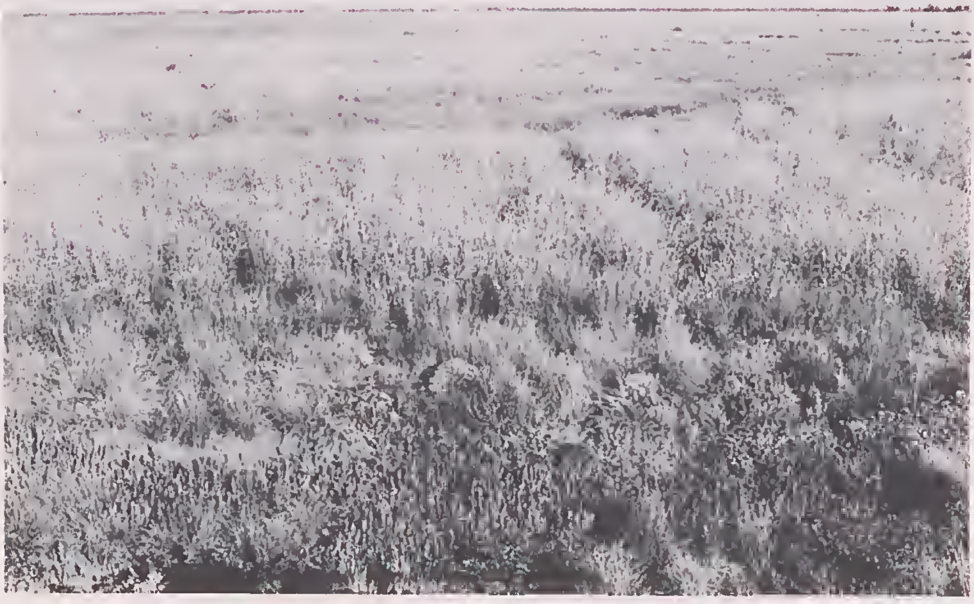


Figure 16. *Astrebla lappacea* grassland (Map unit 39). 30 km north-east of Tilpa (30° 22′ S 144° 15′ E).

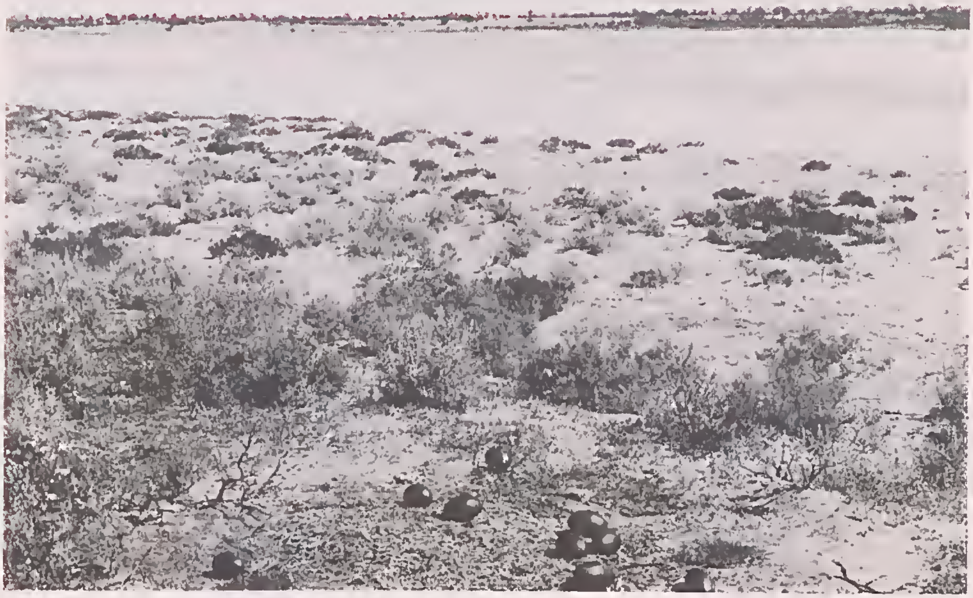


Figure 17. Salt lake communities (Map unit 41). The Salt Lake, approximately 100 km south of Tibooburra (30° 07′ S 142° 05′ E).

Artesian mound springs and *Eriocaulon carsonii*

By far the most unusual and rare habitats in the map area are the artesian mound springs on the eastern and western sides of Peery Lake east of White Cliffs. These springs are still flowing despite drawdown in artesian waters caused by a century of overuse and waste. The western springs are now unique in NSW because they have the only known population of the sedge *Eriocaulon carsonii*. This species is restricted to a single mound on the western side of Peery Lake. Nearby are numerous other apparently similar mounds which do not support the plant. The springs have been heavily used for European management for over 100 years and are heavily grazed by domestic and feral stock. At least one spring was tapped for a permanent water supply, but this is now derelict. The mound with *E. carsonii* is submerged by the waters of Peery Lake for up to 18 months, apparently without harm (Pickard 1992 a, b, c, d).

Management proposals in Pickard (1992 b) include fencing off the springs with stainless steel wire and posts to minimise damage to the fence from rusting when the lake is full, and sinking a new bore to replace the springs as a water source. Another recommendation suggests research into propagation of the plant. The recommended program involves the grazier as an integral component of the plan.

A survey of all mound springs in the Western Division (Pickard 1992 d) indicates that very few are suitable habitat for introducing *E. carsonii*. Indeed, there is no evidence that the plant ever occurred on any other spring except the now extinct Wee Watta Spring north-west of Tilpa.

Conservation areas

Since European settlement virtually all of the Western Division has been subjected to the trampling of hard-footed stock or feral animals and the grazing and browsing of these introduced herbivores (Denny 1987, Benson 1988, 1991, Mitchell 1991, Morgan & Terrey 1992, National Parks Association of NSW 1988, Pressey 1990, Pressey et al. 1990).

Most of the land in the Western Division is publicly-owned leasehold administered by the Western Lands Commission. However, some portions come under the control of the NSW National Parks & Wildlife Service and the Forestry Commission of NSW.

National Parks, Nature Reserves and Historic Sites

The National Parks and Wildlife Service of New South Wales administers three National Parks, nine Nature Reserves and two Historic Sites within the map area where adequate conservation of the plant and animal communities is ensured (Fig. 15). The total area of these (Table 2) is approximately 721,440 ha, representing 2.7% of the map area.

Forest Preserves

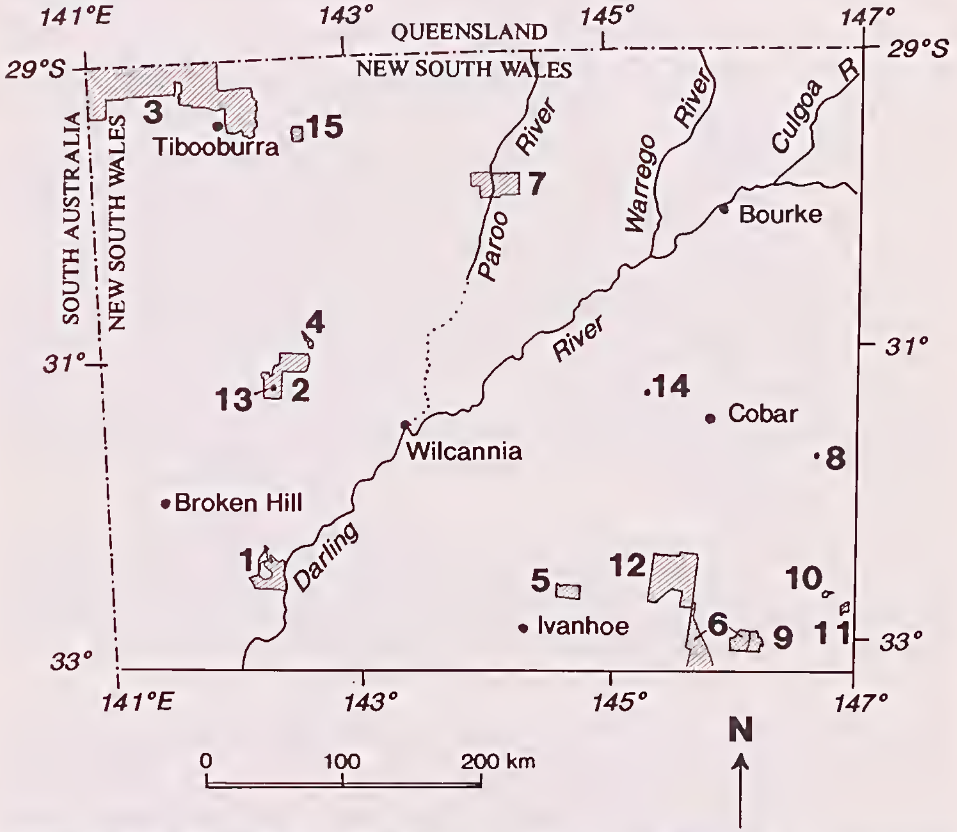
Forest Preserves are under the control of the Forestry Commission of New South Wales. The tenure of Forest Preserves has no legislative backing, whereas Flora Reserves can only be revoked by an Act of Parliament. Until Forest Preserves are established as Flora Reserves their conservation is not guaranteed.

Scrubby Mountain Forest Preserve (F.P. No. 252 in Balowra State Forest) in the Cobar district is the only Forest Preserve within the map area. It comprises sedimentary stony hills and carries *Callitris glaucophylla* associated with *Eucalyptus populnea* subsp. *bimbil*, *Eucalyptus intertexta*, *Eucalyptus sideroxylon* and *Eucalyptus microcarpa* (narrow-leaved form), plus the mallee species *Eucalyptus socialis*, *Eucalyptus dumosa*, *Eucalyptus viridis* and *Eucalyptus morrisii*. The area has had little human disturbance for a long period (Forestry Commission of NSW 1989).

Table 2. National Parks, Nature Reserves and Historic Sites within the map area (data from Property Services, NPWS, Sydney)

	Name	**Area (ha)**
National Parks (NP)	1. Kinchega NP	44,182
	2. Mootwingee NP	68,912
	3. Sturt NP	310,634
Nature Reserves (NR)	4. Coturaundee NR	6,688
	5. Kajuligah NR	13,660
	6. Nocoleche NR	74,000
	7. Nombinnie NR	70,000
	8. Quanda NR	854
	9. Round Hill NR	13,630
	10. Tollingo NR	3,232
	11. Woggoon NR	6,565
	12. Yathong NR	107,240
Historic Sites (HS)	13. Mootwingee HS	486
	14. Mount Grenfell HS	1,357
Total area		**721,440**

Figure 18. Location of National Parks, Nature Reserves, Historic Sites and Aboriginal Area.



National Parks 1. Kinchega; 2. Mootwingee; 3. Sturt: **Nature Reserves** 4. Coturaundee; 5. Kajuligah; 6. Nombinnie; 7. Nocoleche; 8. Quanda; 9. Round Hill; 10. Tollingo; 11. Woggoon; 12. Yathong: **Historic Sites** 13. Mootwingee; 14. Mount Grenfell. **Aboriginal Area** 15. Pindera Downs.

Potential problems in vegetation management

Grazing by domestic stock

Grazing started in the Western Division in the 1850s and has continued to the present. There is no doubt that grazing, past and present, is the single most important influence on the landscape. The magnitude of the impact cannot be overstated. Further, given that the bulk of the land is leased in perpetuity for grazing, the future of the landscape is intimately tied to future grazing management. This has important implications for conservation and is discussed further below. There is abundant evidence that current levels of grazing continue to have detrimental effects on the vegetation. Before considering the arguments advanced to support this assertion, it is necessary to briefly review changes in the vegetation, environment and management of the area. The information presented includes summarised field evidence collected between Wilcannia and White Cliffs (Pickard 1990a, 1990b, 1991a, 1991b, 1994, in press b).

The first graziers to settle the semi-arid rangelands found what they considered to be limitless feed. The only restriction to their operations was water. Once they augmented the few permanent waterholes with dams and wells, they simply kept on increasing stock numbers. At the same time, seasons continued with good rainfall. Unfortunately, the graziers had confused high standing biomass with high productivity. The low productivity of the vegetation was unable to cope, and the enormous numbers of stock led to widespread devastation of vegetation, erosion, and siltation. At the same time, economic depression wiped out the markets for wool. The net result was both ecological and financial ruin (Royal Commission 1901). At the end of the 19th century, stock numbers had fallen from their peak, never to rise to such heights again.

For the next several decades, the landscape bore the scars of the pioneers' management: enormous scalds, dust storms, little regeneration, etc. (Holmes 1938, Beadle 1948). Seasons were generally poor, with low rainfall. The landscape and the vegetation continued in the state left by the damage of the 19th century.

After the Second World War, things changed: higher rainfall, better financial returns, more investment in improvements, more intensive management, better transport systems, and for the first time, effective control of rabbits. At the same time, the landscape began to heal: scalds reduced in number and area, dust storms receded and some regeneration occurred (Condon 1986, Palmer 1991). That these changes have occurred is not open to dispute; but the cause is, and this is quite critical to the future management of the vegetation. There are three main arguments presented to account for the changes.

The first, and the argument most favoured by graziers, is that management has improved enormously since World War II and with more watering points and fences, and with control of rabbits, grazing has less impact than previously (Palmer 1991). Even acknowledging the benefits of rabbit control, the other factors in this argument are difficult to support when all available evidence is examined (Pickard 1991c, 1994). There is still very little or no regeneration of palatable shrubs over enormous areas.

The second argument, supported only by Condon (1986), asserts that changes in legislation and administration of the land through closer settlement is the main cause. There is very little evidence to support this claim.

The third argument suggests that increased rainfall since 1947 has been the primary factor with secondary assistance from rabbit control. This accounts for the fact that stock numbers over large areas have increased since then at the same time that scalds have regenerated naturally. This would only be possible if there was more feed to support the stock (Pickard 1990a, 1994).

This debate is crucial to the future of the vegetation. The root of the disagreement lies in what is considered acceptable damage to the landscape, and what levels of stocking are acceptable. It is likely that many graziers are unaware of the more subtle changes that have taken place. Everyone can see, recognise and understand the impact of scalds and "woody weed" invasion. But how many graziers are aware that losing the top 5 cm of soil in *Acacia aneura* shrubland results in the loss of the bulk of the nutrients (Pressland et al. 1988)? A soil loss of 5 cm would not be detected by most graziers. Yet this is the magnitude of loss that probably still occurs as a consequence of grazing at currently accepted levels in the Western Division.

Although overstocking is prohibited under the Western Lands Act (s. 18D 1 v), there were numerous examples of overstocking during the 1991–1992 drought. Anecdotes relate how thousands of sheep died from starvation. This will only occur if there is no feed available: by definition, this is overgrazing. However, while this may have a severe and long-lasting impact on the soil through erosion and sedimentation, its impact on vegetation may be exaggerated (see below).

The impact of herbivores is not uniform across the semi-arid landscape. Favoured areas of high productivity are grazed more heavily. These areas probably supported the highest populations of native fauna before European settlement (Stafford Smith &

Morton 1990). The disruption and destruction of these habitats has had serious impacts on fauna (Morton 1990).

Regeneration of palatable canopy species

Traditionally it is assumed that present grazing is relatively benign compared to grazing at the end of the 19th century. Proponents of this view argue that the vegetation was devastated by vast numbers of stock to generate enormous profits for rapacious absentee owners (Palmer 1991). However, as noted above, palatable shrubs are not regenerating over most of the map area. Thus current grazing levels are too high to guarantee the long-term future of most of the vegetation (Pickard in press b). Consequently, unless there are fundamental changes in grazing regimes, it is not possible to guarantee long-term survival of the vegetation and landscape. Effects of present (and past) regimes on native fauna (both vertebrate and invertebrate) are also significant and of course relevant to vegetation and ecosystems at large.

It is crucial to realise that rainfall has essentially no influence on the outcome, and that these are not seasonal effects to be dismissed by graziers and their organisations with assertions such as: "It's the drought mate. This is good country. She always comes back after decent rain." There is abundant evidence to show that these are long-term effects over decades covering both good as well as bad seasons. Three examples will suffice here. For others, see the studies quoted in Pickard (1991c). Over at least three decades, *Acacia papyrocarpa* has only regenerated in semi-arid South Australia where seedlings are protected from both sheep and rabbits. *Casuarina pauper* and *Alectryon oleifolius* did not regenerate in south-western NSW despite heavy rains in the 1970s. The available evidence suggests that rabbits and sheep are eliminating all young plants.

Current damage to the flora and vegetation is independent of rainfall. The common link over a wide geographic range is grazing by sheep and feral animals, especially rabbits. The root cause is too many herbivores trying to survive on low-productivity land. Consequently, grazing at currently accepted and acceptable levels is the single major problem facing semi-arid Australia (Pickard in press b).

The basic issue with grazing management is simple and can be reduced to very few words: too little feed, too many mouths. Like many environmental problems, the technical aspect of the solution is trivial: reduce the number of mouths. But because of a complex web of personal, financial and political reasons, the social aspects of the solution appear intractable.

There is now increasing evidence that comparatively low stocking rates actually increase net income while encouraging land regeneration (Purvis 1986, Morrissey & O'Connor 1988). The impact of so-called 'minimal stocking rate' systems on conservation values is unknown. However, vegetation does regenerate with these systems, and as vegetation forms the basis of the food chain for most animals, the systems are worth investigating.

In any event, there is no doubt that only a financially secure grazier can afford to be worried about conservation of non-income producing components of the landscape. Therefore it is essential to quantify these impacts over a range of environments.

Currently, the solution appears to lie in 'minimal stocking rate' grazing systems that have been developed by graziers (Purvis 1986, Morrissey & O'Connor 1988). While these have been shown to generate more income for the grazier, their impact on conservation of the landscape is unknown.

"Woody weeds"

Substantial increases in numbers and density of several species have earned them the pejorative expression "woody weeds": unpalatable native shrubs (e.g. *Senna artemisioides, Dodonaea viscosa* ssp. *angustifolia, Dodonaea viscosa* ssp. *angustissima, Eremophila mitchellii, Eremophila sturtii*). It is generally accepted that these are a form of land degradation because they lower production in terms of sheep, wool, lambing percentages, and profitability (Burgess 1988). While there is some evidence that soil erosion may be higher in dense stands of "woody weeds", there is very little evidence that they are causing any problem with respect to biodiversity.

It is generally considered that "woody weeds" have increased in density because of the lack of regular fire. Domestic stock have removed all the available biomass (fuel) and thus there are now fewer fires than before European settlement (Booth 1985). Thus the plants are responding to a radically changed environment, and are a consequence of grazing. (There is growing field and experimental evidence in Texas, USA, that similar species there are responding to increased CO_2 levels in the atmosphere since the mid-19th century (Johnson et al. 1992, Mayeux et al. 1992, Bahre 1991). If this is the case, then "woody weeds" are in fact, the new vegetation of a large proportion of the semi-arid landscape.)

Environmental weeds

Many exotic plants occur in the map area, but only a relatively small number can be regarded as serious invaders. Perhaps the most serious environmental weed (Humphries 1992) is *Prosopis* spp. (Mesquite). The spiny shrub is mainly located from Broken Hill north to Packsaddle, but has also been recorded from the floodplain of the Darling River southeast of Wilcannia. However, the species occupies hundreds of square kilometres in the upper catchment of the Paroo River in Queensland. Seeds will be carried downstream by floods and will eventually spread into the lower Paroo in New South Wales. Once established, the plant forms dense impenetrable thickets in all suitable habitats. Creek lines and alluvial plains are favoured habitats. As seeds last up to 40 years in the soil, once the species occurs in an area, it is almost impossible to eradicate. *Prosopis* is (barely) controlled with herbicides and is currently listed nationally as a target for biological control.

Lycium ferocissimum (African Boxthorn) is widespread on scalded plains east of White Cliffs, near Ivanhoe and elsewhere, and often close to old watering points on sandplains. The spiny shrub spreads via seeds in bird droppings and in flood debris. Once established, it can form dense thickets, but plants are killed by prolonged droughts (e.g. 1991–1992 drought). When abundant, the plant completely changes the structure of the vegetation. Thus, low open-shrublands of *Maireana* spp. are transformed into *Lycium* Open-shrublands. *Lycium* may have some value as a nesting site for small birds which appear to find shelter from predators in the dense spiny shrubs, and even when dead, the shrubs afford considerable protection.

Xanthium spinosum (Bathurst Burr) and *Carthamus lanatus* (Saffron Thistle) are widespread roadside weeds spreading into suitable sites. *Xanthium* is generally restricted to wetter areas, such as ephemeral creeks. In favourable (wet) seasons, local populations may be extremely dense, and set abundant seed to maintain the infections. In contrast, *Carthamus* is more widespread in drier sites and has been gradually spreading in the area for the past few decades. It is most often seen as dead plants, but the seeds are very long-lived and thus, once established, the plant can quickly appear from seeds in the soil when suitable moisture conditions prevail. Currently there is virtually no systematic attempt at controlling either species. Given the relative values of the land, cost of control, and anticipated benefits from control, concerted efforts at control are unlikely.

Conservation options for future management of the vegetation

Alternative approaches to vegetation management for conservation

In the Western Division the approach of the NSW National Parks and Wildlife Service has been to acquire land with perceived high conservation values, though some land has been acquired merely because it was vacant. An important aim is to have one sample of every land system in a formal reserve. This is one of the most popular objectives of conservationists, but is probably politically unlikely (Pressey & Nicholls (1989). For this, and other cogent reasons, it is apparent that formal conservation areas need to be complemented by off-reserve conservation procedures to achieve goals of environmental conservation. Such procedures include negotiating agreements with landholders whose land covers sites deemed to be of high conservation value — for example the proposals recommended to conserve the rare *Eriocaulon carsonii* discussed above. Such negotiations could conclude with a range of measures that satisfy both the conservation objectives and the aspirations of the landholder: formal contracts, informal agreements, covenants on titles, and combinations of these. The landholder should be compensated in an appropriate manner for foregone income.

However, the implications of the findings of Pressey & Nicholls (1989) should be noted. Piecemeal attempts at reserving examples of environments are not the best approach. Instead all options for the Western Division need to be addressed as a whole. There are problems with this. When the National Parks and Wildlife Service seeks to purchase properties in the Western Division, particularly during periods of rural depression, it is perceived by remaining graziers as being opportunistic. Interestingly, other purchasers would not be regarded in this light, demonstrating a double standard among graziers. Further, potential problems caused by graziers being financially unable to maintain improvements over the past few years have been ignored by neighbours. As soon as the Service acquired any land, these would immediately jump to prominence and may be considered the fault of the Service. There are no easy solutions to these problems. They are merely the corollary of acquiring land for environmental conservation.

Currie & Hacker (1990) argue that in arid Western Australia grazing may be compatible with conservation. There is however a dearth of relevant information on the impact of different grazing systems and styles of management on the vegetation of semi-arid NSW. Some semi-arid lands in South Australia are currently managed for multiple uses; grazing, recreation, mining and conservation (Cohen 1990). Experience to date has been promising despite some initial problems. Legislation in the United States requires multiple use of Federal land for grazing, logging, recreation and conservation (Clawson 1983). In principle, each parcel is considered to determine which use should be given priority. In practice, existing grazing use is often given preference (Jacobs 1991).

Combining these arguments with those expounded earlier, it is clear that successful off-reserve conservation is predicated on both successful negotiations (every party wins and achieves their own goals), and landscape management that is sensitive to conservation objectives. In general terms it is known (and accepted by most graziers, and all agencies) that excessively heavy grazing leads to land degradation; soil erosion, vegetation structure changes, and perhaps "woody weed" invasion. What is not so widely accepted is that grazing levels that are currently considered to be safe are also causing land degradation (Pickard 1991a, c).

Before being involved in off-reserve conservation on their properties, graziers need to be convinced that they will not suffer financially. As the normal approach suggested is to lower stocking rates, this does not appear very convincing to many graziers

(Pickard in press b). However, there is now increasing evidence that comparatively low stocking rates actually increase net income while encouraging land regeneration (Purvis 1986, Morrissey & O'Connor 1988). The impact of these 'minimal stocking rate' systems on conservation values is unknown but it is essential to quantify these impacts over a range of environments.

Acknowledgements

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Rainforest stands between Barrington Tops and the Hunter River, New South Wales

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Turner, J.C.[1] *& Vernon, S.L.*[2] *([1]21 Tyrrell St, Newcastle, NSW, Australia 2300; [2]Hunter Catchment Management Trust, High St, Maitland, NSW, Australia, 2315) 1994. Rainforest stands between Barrington Tops and the Hunter River, New South Wales.* Cunninghamia *3(3): 465–514.* The environmental settings and floristic compositions of 46 rainforest stands are examined. The stands, of total area about 850 ha, were selected from some 3 700 km^2 of foothill country north of the Hunter River towards the southern scarp of Barrington Tops. The surveyed stands (median area: 15 ha) have characteristics typical of the dry rainforest sub-formation: several emergents (*Ficus* spp. and *Brachychiton discolor*), rich tree and woody climber components, relatively small numbers of shrub, fern and epiphyte species, and a sparse ground stratum. They contain about 200 species, excluding grasses, sedges and eucalypts. The stands form a fairly homogeneous group, with relatively little compositional change evident across the survey area. The three most abundant and widespread tree species are (in decreasing order) *Streblus brunonianus, Mallotus philippensis* and *Capparis arborea.* This is the southernmost occurrence of such a large area of floristically and structurally well-developed dry rainforest. No rare or threatened plant species are known to be present, but 11 rainforest species are thought to reach their southern limits in the survey area. With one exception, the stands are in private ownership, with no legal protection from disturbance. Their current conservation status is therefore very unsatisfactory.

Introduction

Much of the remaining rainforest in NSW is now in National Parks and Nature Reserves, where it is fully protected, or in State Forests, where present policy gives most of it some protection. However, a large number of smaller stands lie outside such protection and most of them have not yet been systematically examined.

In the Hunter Valley, because of the particular patterns of rainfall, landforms and lithology, most of the remaining rainforest lies between Barrington Tops and the Hunter River (Figure 1), as did most rainforest before European settlement. All of the northern section of this tract is in the Barrington Tops National Park and in State Forests. The rainforest stands in these locations are not threatened by human activity and are relatively well known botanically (e.g. Fraser and Vickery, 1938; Bowden and Turner, 1976; Turner, 1976; Floyd, 1990). However, the lower and more southerly parts are largely in private hands and contain several hundred rainforest stands, many of them still in good condition, whose structure and composition are complementary to those of the stands in the immediate Barrington Tops area. These surviving stands are generally conspicuous in the foothill landscapes, especially because past clearing practices have often left a stand mostly untouched while the surrounding eucalypt forest has been wholly or partially removed. Although many stands have escaped wholesale clearing up to the present day, they are exposed to disturbance by cattle, fire, the invasion of weeds, and such activities as timber-getting and track construction.

Four rainforest sub-formations occur in this part of the Hunter Valley: cool temperate, warm temperate, sub-tropical and dry (Williams, Harden & McDonald 1984, pp. 6–7). Cool temperate rainforest, above about 900 m altitude, warm temperate rainforest, immediately below 900 m, and sub-tropical rainforest in the valley floors close to the southern scarp of Barrington Tops, are almost wholly contained within the National Park and State Forests. Further south, recent examination of a few of the foothill stands mentioned above (Floyd 1983a; Vernon 1985) showed that they consist predominantly of dry rainforest, with some internal gradation towards sub-tropical rainforest.

This paper reports the results of an examination of the floristic composition and other characteristics of a sample of rainforest stands north of the Hunter River to the southern boundaries of the publicly-owned land close to Barrington Tops. The eastern boundary of the overall study area is the eastern edge of the Williams River drainage basin, and the western boundary is the western edge of the Foy Brook basin

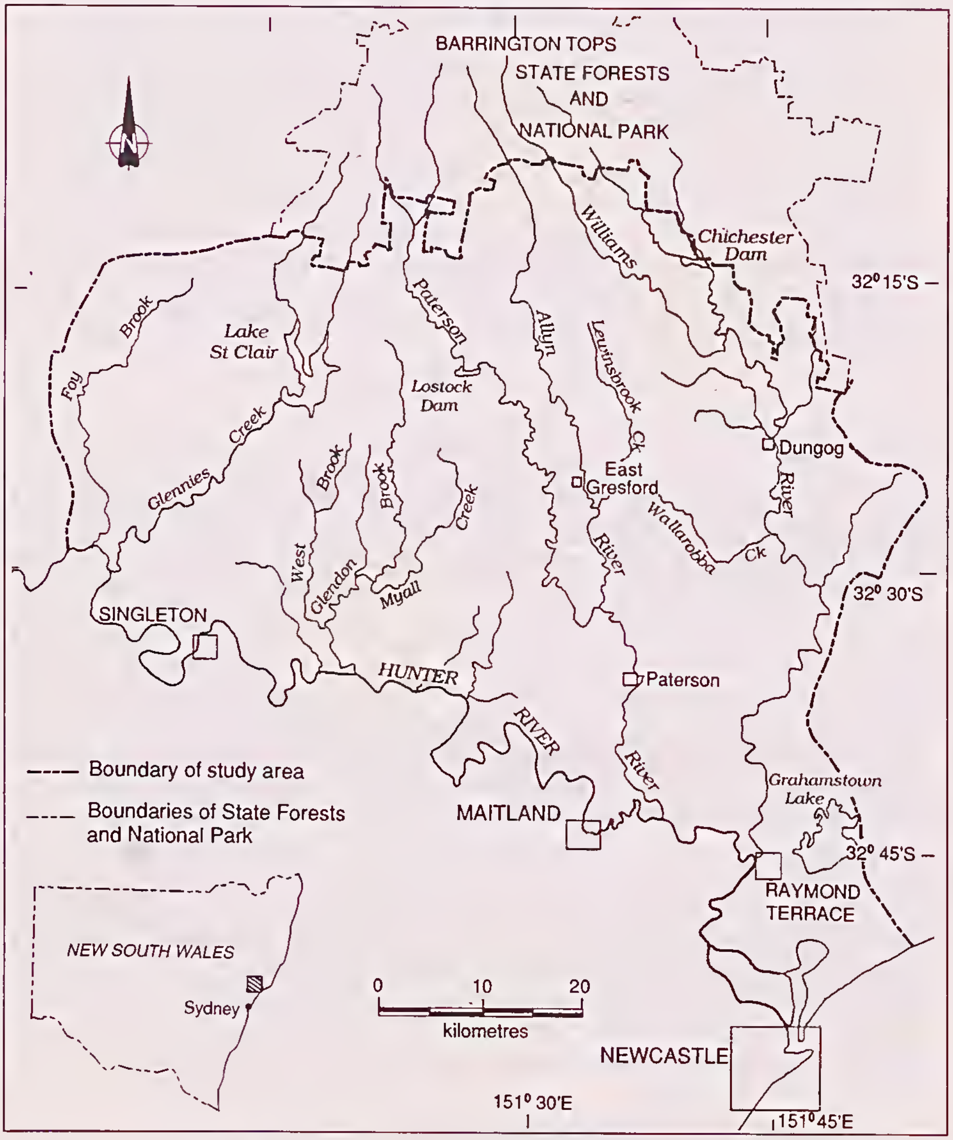


Figure 1. Map of the study area. The southern boundary is the channel of the Hunter River.

(Figure 1). The study area covers about 3 700 km^2 and includes the small towns of Dungog, Gresford and Paterson. The material in this paper is taken from a more extensive, unpublished report prepared under a National Estate grant (Turner and Vernon 1990).

Physical Setting

Drainage and relief

The major streams of the study area (Williams, Allyn and Paterson Rivers) have their beginnings on or close to the southern scarp of Barrington Tops, and their valleys radiate away from it towards the Hunter River. Even such shorter and lesser streams as Glendon Brook, Glennies Creek and Foy Brook are a part of this radiating pattern (Figure 1). Most of the study area lies below 500 m. In this foothill country, the higher land occurs as ridges between the river valleys. Typically, local relief (the difference in elevation between a main valley floor and the nearest basin divide) is 200 m to 300 m. The floors of the main valleys are generally broad and open.

Rainfall

The isohyet map of Figure 2 has been drawn from annual averages (Bureau of Meteorology data) for some sixty of the stations contained in the atlas assembled by Bridgman (1984). The data are so sparse across the whole area that we have not felt

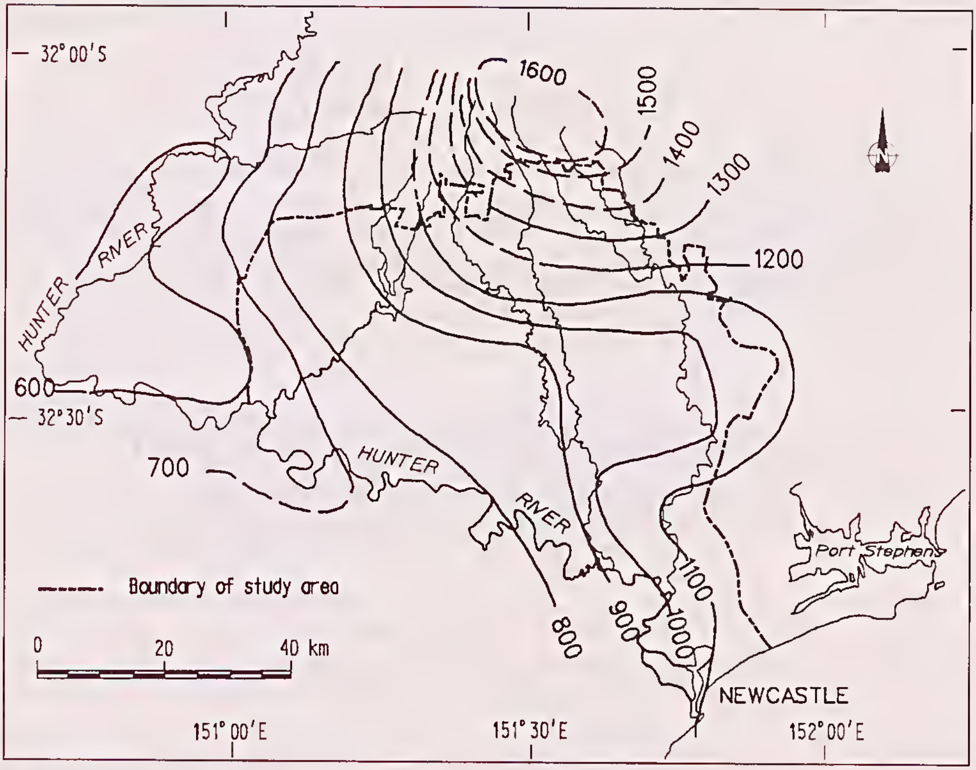


Figure 2. Isohyet map of the study area and vicinity. Smoothed isolines of average annual rainfall in mm.

justified in drawing other than highly-smoothed isolines. Locally, one would expect to find a far from smooth pattern because of aspect and topographic influences. Thus, Figure 2 is only a generalised picture of the annual average rainfall of the area. It probably presents an underestimate of actual rainfall on the higher parts of the foothill country on those parts where most of the remaining rainforest stands occur. Regionally, annual rainfall is positively correlated both with closeness to the coastline and with altitude. Across most of the study area the isohyets lie in a south-east to north-west direction.

Geology and soils

Almost all the rocks in the study area are of Devonian and Carboniferous age, many of them very resistant to weathering. Galloway (1963) has given a brief geological description of the Hunter Valley, including the study area.

Both Galloway (1963) and van de Graaff (1963) point out that the soils found on the more resistant rocks are usually skeletal. A small amount of analytical information is available for such soils. One of us (Vernon 1985) has reported on some characteristics of the top 10 cm of the soils she found in four rainforest stands (coded here as C1, C3, W1 and W2). These stands span most of the southerly part of the survey area, in a south-east to north-west sequence. The soils were relatively coarse in texture (ranging from silty loams to loamy sands) and slightly-to-strongly acid. They contained about 10% organic matter and their total phosphorus concentrations were no more than moderate (mean values 0.042% to 0.061%). These four stands occur on acid-to-intermediate vulcanogenic rocks such as rhyodacites, parent materials typical of the range of parent materials underlying the stands examined in detail in this present survey. We expect therefore that the soils of most of the surveyed stands will be very free-draining and of low-to-moderate chemical fertility and water-retaining capacity.

Land systems and landforms

Land systems are 'areas with (their) own characteristic (and recurring) combination of landforms, soils and vegetation' (Story et al.). Stands were assigned to the land systems used in the CSIRO survey of the Hunter Valley (Story et al. 1963), and based on their 1:250 000 land system map sheet. Abbreviated descriptions of the relevant landforms are given below.

Cranky Corner	Extremely steep massive mountains, hills, escarpments [and] deep ravines with rubbly slopes and cliffs, up to [60 m] high.
Mt Butterwicki	• Very steep ridges with narrow crests dissected by closely-spaced ravines giving extremely broken topography; much outcrop; liable to slumping. • Massive hills with extensive cliffs and much surface rubble. • Deep narrow valley heads, generally facing south, bounded by cliffs or very steep slopes; much surface rubble.
Mt Royal	Fairly steep to very steep ridges with broadly rounded summits or narrow crests; slopes dissected by closely-spaced ravines.
Rainforest	• Steep ridges with narrow uneven crests; slopes with closely-spaced deep ravines or with cliffs and bluffs [3–60 m] high. • Basalt screes and cliffs.
Wallaroo	Moderately steep rounded hills [15–100 m] high; lower slopes of major valleys in more rugged areas; broad structural benches andplateaus fringed by cliffs and bluffs up to [15 m] high.

Methods

Air reconnaissance

We decided that systematic low-level aerial reconnaissance, with a colour photographic record, would provide the most effective basis for selecting stands for ground visits. Standard black-and-white stereo aerial photographs were used to supplement the information gained from these light-plane flights where required. Eleven reconnaissance flights were made in Cessna aircraft, covering the whole study area. The flight path was usually 300–500 m above local terrain. At these elevations, a lens of 50 mm focal length on a 35 mm camera gave satisfactory cover of most rainforest stands.

Ground survey

Criteria used in the selection process were size, relative freedom from human-induced disturbance, representative location within the survey area, physical accessibility, and the granting of permission for entry from the land-owner.

We accepted as a working assumption that the larger a stand, the richer in plant species and the more fully developed structurally it was likely to be. In addition, freedom from at least gross disturbance was a self-evident requirement — this was a characteristic which, it was found, could be assessed satisfactorily from direct observation on light-plane flights and from the resulting colour transparencies. Concerning location, we felt that, as well as there being a requirement for breadth of sampling (i.e. across the whole survey area), there was a need for increased intensity of sampling in areas where stands were relatively large and frequent.

Physical difficulty of access prevented visits to a few remote stands, such as some in the upper parts of the valleys of Glendon Brook and the Paterson River (immediately south of State Forest boundaries). In four cases land-owners either refused or showed marked reluctance to allow a visit. As far as possible, nearby stands of similar size were inspected instead. In the event, 42 stands were examined. In addition, some of the data collected by Vernon (1985) for another four stands have been incorporated into our results.

Within each stand an extended route (usually doubling back and forth) was chosen in order to sample as fully as reasonably possible the range of habitats present, having regard to such influences as local topography and aspect. We aimed to complete the inspection of each smaller stand within a day. However, it took two or three days to examine some of the larger stands. For each stand, the presence and relative abundance of individual species were recorded. Four categories of relative abundance were recognised: very common (VC), common (C), occasional (O) and rare (R). These qualitative abundances were assessed by the same person (SV) for every stand but one (Rosewood Gully, C2), with the aim of achieving as much inter-stand consistency as reasonably possible.

The survey area was divided into three sectors, Eastern (E), Central (C) and Western (W), and the surveyed stands in each sector were numbered in sequence from south to north. Thus each stand has been coded by a letter and a number, e.g. C12. The boundaries between sectors were arbitrarily placed along two of the major streams, the Allyn-Paterson River and Glennies Creek (Figure 3). In a few cases (E4, E5, E11, E17, C14), where two or three small stands were close together and could be inspected as a group during one or at most two visits, they have been given a single code designation.

Rock specimens were collected at most stands. Later they were examined and classified by Dr L.N. Morris of the Geology Department, University of Newcastle.

Landscape data

Area

An outline of each stand was drawn on its 1:25 000 topographic map sheet, using for guidance all the available sources of information: black-and-white aerial photographs (with stereo cover), low-level aerial oblique colour transparencies, our ground-survey records, and the pattern of local drainage and contour lines revealed on the map itself. The area of the stand outline was then determined by tracing it on to graph paper and counting the enclosed number of unit squares.

In most cases, the size of the stand had been reduced by past human disturbance. It is now difficult or impossible to estimate where these edges may have stood before settlement. As mapped, however, the stands consist very largely of rainforest still structurally intact. Particularly at the down-stream margins of many stands, there are clear signs of recent and continuing disturbance: broken canopy, lack of normal vertical structure, weed invasion, livestock incursions. Care was taken to try to exclude such areas from the mapped stand outlines.

Eucalypts occur intermingled with rainforest species in many stands — sometimes singly, sometimes in patches, and almost always towards the edges of stands. Mapping is always difficult in such circumstances. Here, we have included single eucalypt trees and very small groups within the stand outline, but have excluded larger groups. The latter commonly occur on ridge lines within the general confines of the larger stands and they are present, for instance, in the Tabbil Creek stand, E10. Very commonly they have a rainforest understorey.

Rainfall

To obtain an estimate of the average annual rainfall of each stand, linear interpolation was applied between the smoothed isohyets shown in Figure 2. No adjustment was attempted for local topographic patterns, although it was recognised that all the stands examined were in upland sites, commonly with southern or eastern exposures, while most of the measuring stations were on the relatively open floors of the major valleys, kilometres or tens of kilometres away.

Altitudes and altitudinal spans

From the outline of each stand drawn on to its 1:25 000 map sheet, the altitudes of the highest and lowest boundaries were read off to the nearest 10 m. The mid-point of these extreme values was then taken as a mean value for the altitude of the stand. The altitudinal span of a stand was taken as the difference between the two extreme values.

Aspect and slope

A subjective assessment of the predominant aspect of each stand was made by inspection of the stand outline drawn on the appropriate 1:25 000 map sheet. The 16-point compass scale was used as the basis of this assessment.

A measure of the overall slope above horizontal of each stand was obtained by measuring, on the 1:25 000 map sheet, the straight-line distance between the highest

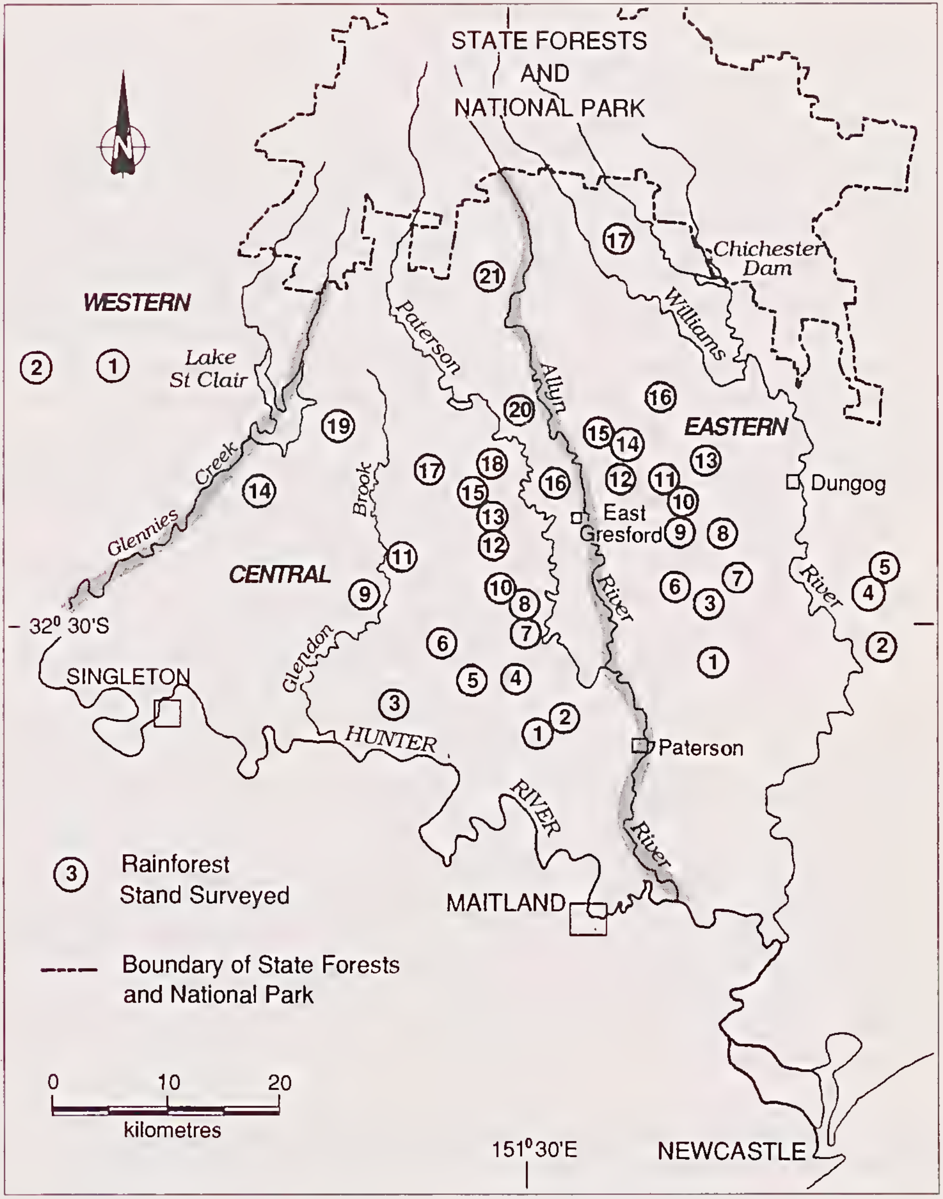


Figure 3. Distribution map of the surveyed stands: Eastern, Central and Western sectors.

and lowest points in the stand (points of known altitude — see earlier) and applying the arctangent relationship to find the angle.

Plant data

Compilation of species lists

Lists of the plants found in the surveyed stands are presented in Appendixes 2 and 3. For some stands occurring very close together, only composite species lists were prepared. Appendix 1 (see further mention in Results) therefore describes more stands than are apparent in the columns of Appendixes 2 and 3 (see Notes with these two Appendixes). Plant names have been checked against Harden (1990, 1991, 1992) and against Beadle (1971–1987) where appropriate.

The distinction between shrubs and small trees is traditionally made on the basis of both height and form. Specht (1970) for instance defines a shrub as 'a woody plant less than 8 m tall, frequently with many stems arising at or near the base'. In rainforest, however, our observations indicate that most small free-standing woody plants are not multi-stemmed, so it is necessary to draw a dividing line, arbitrarily, on a size criterion alone. We prefer to base the decision on the easily-measured or estimated property of stem circumference at breast height (1.4 m), following the definition: 'a shrub species is a population of woody plants whose members do not consistently attain, at maturity, a stem circumference at breast height greater than 10 cm'. On this criterion, most of the woody plants in question are defined as (small) trees and accordingly our species list for shrubs (Appendixes 2 and 3) is quite short.

We have followed the practice of Floyd (1983a) and have not included eucalypt species in the rainforest species lists. Eucalypts almost invariably occur only near the edges of these dry rainforest stands. *Casuarina cunninghamiana* occurs along some of the larger streams running through stands (e.g. along Webbers Creek in the Moonabung Falls stand, C1). It can be thought of as occupying an internal edge habitat. Two *Melaleuca* species, *M. quinquenervia* and *M. styphelioides*, occur through the stands — the latter species is quite common. In contrast to the eucalypts, these three species have been included on the lists. Eucalypts generally cannot regenerate under a rainforest canopy, so their presence in a stand (perhaps initially due to an incursion by fire) is essentially fortuitous and for a single generation. On the other hand, as far as we know, the *Casuarina* and *Melaleuca* species are stable in their present positions and are able to persist indefinitely.

It is inevitable that some species actually present in an individual stand will not be detected. A species missed in one stand, however, is likely to have been noted in one or more other stands (unless it is of very restricted distribution) — more confidence can be placed on the overall occurrence list than on the presence list for any individual stand. It should be noted too that different weights are necessary when one considers presences compared with absences. A recorded presence is unambiguous but an indicated absence is less clear-cut in its meaning — it may truly be an absence, or it may cover a failure to detect a presence.

We have some data on the effectiveness of sampling of stands. They concern stand C1, Moonabung Falls. In 1982 this stand was surveyed by Floyd (1983a), using very much the same method as we used with other stands: a more-or-less systematic walk through the stand, noting presences. In 1985, detailed plot-work was carried out in the same stand by Vernon, who examined 27 plots each of area 200 m^2, placed systematically throughout the stand. In Table 1 we compare the results of the two examinations by way of listing the numbers of species detected in the structural groups. Our general expectation is confirmed that a reconnaissance survey tends to yield fewer recorded presences than the results of detailed plot-work across the stand.

Three other stands (Sandy Waterholes, C3; Foy Brook, W1; and Cedar Creek, W2) were also examined in detail by Vernon (1985). As well, another three of the stands surveyed by us had also been surveyed earlier by Floyd (ibid.) in the same way as his examination of Moonabung Falls. For these stands (Mirari Ck, E6; Pilchers Mountain, E8; and Tabbil Ck, E10) the two presence lists have been combined. Thus, the surveyed stands have been subjected to a range of sampling intensities, and the comprehensiveness of their species lists is likely to vary accordingly.

Cluster analysis of the stands

A polythetic agglomerative classification procedure was applied to the stand-by-stand tree species-presence data. In the so-called 'flexible fusion' strategy (described in Williams, 1976), the relative amount of space contraction–dilation allowed in the clustering process is termed the beta value. A small negative beta value has commonly been found to be optimal in obtaining sought-after sharpening of distinctions between nearby clusters. Commonly, a beta value of –0.25 is used. Here, we used SAS Statistics software, procedure CLUSTER (METHOD = FLEXIBLE, beta = –0.25), followed by procedure TREE, which prints a dendrogram as well as the fusion history of the agglomerative steps.

Included in the analysis was the species list termed Wg (Appendix 2), for those rainforest species occurring generally in the Western sector, often as single trees or in very small groups. For present purposes, the Wg list will be termed a 'stand'. The final data matrix contained 44 stands and 85 tree species. A few species were not included because of their low inter-stand frequencies — only one or two occurrences in the 44 stands.

Results

a) The stands in their landscapes

Location

Locational and other information about the stands is presented in Appendix 1. Most of the surveyed stands are concentrated in the stretch of country from Dungog west–south-west towards Singleton. We consider that this pattern mirrors with fair accuracy the density of distribution of stands as a whole, particularly of the larger ones. Stands are small and infrequent in the western part of the survey area. Here, species of undoubted rainforest affinity occur, but in very small groups or, commonly, as isolated individuals. These species, tolerant of relatively dry habitats, will be referred to again later. The scale of their distribution patterns in the west (where the term 'stand' is frequently no longer appropriate to describe their form of occurrence) makes for difficulties in any attempted comparison with stands in the east, which usually are coherent and well-defined, and may be quite large.

Table 1. Comparison of observed species numbers between a reconnaissance survey (Floyd, 1983a) and systematic plot work (Vernon 1985) at Moonabung Falls (stand C1)

Structural group	Numbers of native species		
	from a single reconnaissance visit	from plot work	reconnaissance / detailed plot work %
Trees and shrubs	46	67	69
Herbs	8	10	80
Climbers*	17	13	131
Epiphytes and Lithophytes	6	6	100
Overall	77	96	80

* Chalmers and Turner (1994 in press) found 26 species of climbers in this stand. Their expanded list has not been applied to this present report.

Area

The frequency distribution and some statistics of the areas of surveyed stands are set out in Table 2. The frequency distribution is strongly skewed towards larger stands. Mean areas were also calculated separately for the 20 stands in the eastern sector and for the 26 stands in the central and western sectors. As expected, the mean size of the eastern-sector stands (22.6 ha) is markedly higher than that for the stands of the other two sectors (15.8 ha).

Rainfall

For the 46 rainforest stands examined, estimated average annual rainfall values range from 750 mm to 1 400 mm, with most stands in the 800–1 000 mm range (Table 3).

Topographic types and land systems

Our observations suggested that the topographic situations in which stands occurred could be assigned to the following general types.

Down-stream valley site

A down-stream valley stand occurs in a side valley usually well removed (typically kilometers) from the extreme headwater tract of its tributary valley. The presence of the stand is associated with a local topographic feature providing sheltered habitats, perhaps a gorge, e.g. stand C1 below Moonibung Falls.

Gully-head amphitheatre

In some cases there are amphitheatre-like hollows at the extreme heads of streams. These hollows, usually with very uneven and scree-covered floors, provide sheltered

Table 2. Frequency distribution and statistics of the areas of surveyed stands

	Area class (ha)					
	0–9	10–19	20–29	30–39	40–49	≥50
Number of stands (Total = 46)	15	16	8	3	1	3

Mean = 18.7 ha
Standard deviation = ± 17.0 ha
Median = 15.5 ha
Range = 1.5–84 ha

Table 3. Frequency distribution and statistics of the estimated average annual rainfall of surveyed stands

	Rainfall class (mm/year)							
	700–799	800–899	900–999	1000–1099	1100–1199	1200–1299	1300–1399	1400–1499
Number of stands (Total = 46)	2	17	15	9	1	1	0	1

Mean = 930 mm
Standard deviation = ± 1·10 mm
Median = 900 mm
Range = 750–1400 mm

Mean of eastern-sector stands = 1005 mm
Mean of central- and western-sector stands = 880 mm

habitats and often contain rainforest stands. An example is the Pilchers Mountain stand, E8.

Single and multiple gully-heads

At the extreme heads of streams ('gullies' at that stage) rainforest stands often occur. Depending on the local pattern of drainage and topography, a stand may be relatively small and occupy a single gully head, which may have minor tributaries within the stand (e.g. Bingleburra, stand E12), or it may connect across several neighbouring gullies (e.g. Wallarobba Range: NE section, stand E13). In both cases, the stand is often roughly triangular in overall outline, with apex down-slope where a consolidated stream finally emerges.

Weakly-gullied rocky slopes

Some stands occur on very rocky slopes where drainage lines and channels are not strongly developed. In these cases, the stand may be largely underlain by scree and there may be low cliffs immediately above (e.g. the Lees Mountain stand, C7). The presence of rainforest plants may be encouraged on some substrates of fragmented rock because relatively more of the infiltrated rain water is likely to be available to plants than in non-rocky soils. There may also be additional water from run-off from cliffs.

A combined frequency table has been drawn up for all surveyed stands in terms of the land systems and topographic types to which they can be assigned (Table 4). Stands occur on five land systems — they are particularly common on Cranky Corner and Mt Butterwicki, both of which are notable for rugged landscapes. As regards the five defined topographic types, gully heads, both single and multiple, are by far the most common sites for the occurrence of the surveyed stands.

Altitudes and altitudinal spans

The frequency distributions and some statistics of the altitudes and altitudinal spans of the surveyed stands are set out in Tables 5 and 6 respectively. These two frequency distributions, unlike those for stand area and average annual rainfall, are more or less symmetrical in shape, with the modal class centrally placed.

Table 4. Frequency distributions of stands with respect to land systems and topographic types

		Land System					
		Cranky Corner	Mt Butterwicki	Mt Royal	Rainforest	Wallaroo	Total
Topographic type	Down-stream valley site	5	4				9
	Gully-head amphitheatre		4			3	7
	Multiple gully-heads	4	8	1	1		14
	Single gully-heads	5	5			2	13
	Weakly-gullied rocky slopes	1	1			2	4
	Total	15	22	1	1	7	46

Aspect and slope

A combined frequency table for aspect and slope of all surveyed stands is presented in Table 7, together with some relevant statistics. The reader will appreciate the gross approximation involved in the selection of a single direction to represent the diverse array of aspects encompassed in a stand, particularly a large one. Most of the stands have predominant aspects lying from E through SE to SSW.

Lithological background

The rock specimens collected were all of Carboniferous age. They were derived almost entirely from volcanic activity, being either lavas of an acid or intermediate type, or sedimentary rocks (mostly fine-grained tuffs) derived from similar igneous rocks. In these latter cases, the sedimentation seems generally to have occurred in terrestrial environments (L.N. Morris, pers. comm.).

From these findings, it cannot be expected that the fertility of the associated soils will be any higher than low-to-moderate. It seems likely that the surface-soil analytical results for four of the stands (C1, C3, W1, W2; Vernon, 1985) mentioned earlier will be of broad applicability across the surveyed stands. The presence of some ooliths at two of the stands (E2 and E9) suggests that at least some of the soils under these particular stands will be enriched in calcium.

Only one rock specimen was collected from most of the stands. Inevitably some stands, particularly the larger ones, will possess a lithological heterogeneity not revealed in our results. However, even if the sampling had been exhaustive, there would be no reason to expect conclusions about general soil fertility levels different from those set out above.

The modal stand

A number of physical features of the surveyed stands have been described. In Table 8 we summarise the modal characteristics of stands. For those characteristics where a numerical scale is employed, the specific bounds of the modal classes shown in the

Table 5. Frequency distribution and statistics of the mid-point altitudes of the surveyed stands

	Altitude class (m)			
	1–99	100–199	200–299	300–399
Number of stands (Total = 46)	3	9	22	12

Mean = 242 m
Median = 245 m
Standard deviation = ± 77 m
Range = 90–380 m

Table 6. Frequency distribution and statistics of the altitudinal span of the surveyed stands

	Altitude-span class (m)					
	50–99	100–149	150–199	200–249	250–299	300–349
Number of stands (Total = 46)	7	10	16	8	4	1

Mean = 163 m
Median = 160 m
Standard deviation = ± 64 m
Range = 50–310 m

table have been arbitrarily chosen — no great significance or exactitude should be read into the selected limits. The means and medians lie within the respective modal classes, or close to them.

Results

b) The rainforest vegetation

Rainforest structural types

The surveyed stands are examples of dry rainforest. Williams et al. (1984) provide a description of this rainforest type, which they recognise as one of the four sub-formations of rainforest occurring in NSW. Characteristics important in distinguishing dry rainforest from the other sub-formations are listed below in Table 9.

There is no single structural or floristic feature which uniquely distinguishes dry rainforest from the other sub-formations. Each sub-formation grades continuously into one or more of the others. Dry rainforest, for instance, may grade into sub-tropical rainforest along a moisture-supply gradient (in circumstances where temperature is more-or-less constant) or into warm-temperate rainforest along combined moisture and temperature gradients (increasing moisture and decreasing temperature). The sense of continuity between the sub-formations is reinforced by the fact that some species show a very wide environmental tolerance, occurring in three or even in all four sub-formations.

Table 7. Frequency distributions and statistics of stands with respect to predominant aspect and overall slope inclination

Predominant	**Slope-inclination class (°)**				**Totals**
aspect	**5–9**	**10–14**	**15–19**	**20–24**	
N		1	1	2	
NNE		1		1	
NE	1			1	2
ENE		1			1
E	1	2	2		5
ESE		1	1	1	3
SE	3	5	4	1	13
SSE		2	1		3
S	4	1	3	1	9
SSW	2	1	1		4
SW			1		1
WSW			1		1
W					0
WNW		1			1
NW		1		1	
NNW					0
Totals	11	17	14	4	46

SLOPE INCLINATION

Mean = 13.2° **Median** = 13°

Standard deviation = ± 4.6° **Range** = 5°–24°

ASPECT

Mode = south-east **Median** = south-east

Vernon (1985) assessed the four stands which she was studying in terms of the classification system of Webb (1978). She concluded that they could be regarded as examples both of dry rainforest and of simple notophyll low vine forest (Webb terminology), and we think that these terms can be applied to all the stands in the present survey. Even stand E17, Chichester Gap, which is close to the southern scarp of Barrington Tops and is relatively high (mid-point 375 m in altitude) and wet (1 400 mm estimated average annual rainfall), still fits most of the characteristics for dry rainforest (Table 9). All of these stands, however, possess some characteristics linking them to the sub-tropical and/or warm temperate rainforest sub-formations. This is especially so with those (larger) stands occupying a wide range of topographically-determined habitats. Here, in the most sheltered habitats, for instance, the forest may approach, locally, sub-tropical rainforest in its structure and floristics. Later we examine further the notion of the mixed nature of the surveyed stands.

Species frequencies and abundances

Inter-stand frequencies

The inter-stand frequency of a species is defined here as the percentage of all those stands under study in which the species was observed. It provides a measure of the relative degree of spread of a species across the surveyed stands, and gives no indication at all of the intra-stand abundances of that species. The term *frequency* in plant ecology normally applies to the percentage presence of a species across a number of plots, all of the same size. Our surveyed stands (by analogy, to be thought of as 'plots') range widely in area, so there can only be a broad qualitative similarity between these two frequency terms. To provide an indication of variation in inter-stand frequencies *within* the surveyed area, values have also been calculated separately for the eastern-sector stands and for the central- and western-sector stands combined. Table 10 summarises some of the variability in inter-stand frequency. Species have been included in the Table if their inter-stand frequencies in E and in C + W stands differ by twenty or more percentage points. This figure is an arbitrary choice — it is meant to signify a marked difference unlikely to be due to chance alone.

More species show a large inter-stand frequency decline in the east-to-west direction than show such a decline in the opposite direction. This trend is particularly strong for vines and epiphytes/lithophytes. This supports the expectation that many rainforest species will become less frequent as the distance from the coast increases, mainly for reasons of diminished moisture supply, but also connected with reduced

Table 8. The modal stand amongst the forty-six surveyed

Characteristic	Modal class
Area	10–19 ha
Average annual rainfall	800–899 mm
Land system	Mt Butterwicki
Topographic type	Multiple gully heads
Altitude	200–299 m
Altitudinal span	150–199 m
Predominant aspect	South-east
Overall slope inclination	10–14°
Underlying rock type	Fine-grained tuffs derived from acid volcanics
Geological age	Carboniferous

Table 9. Prime distinguishing features of dry rainforest (after Williams et al., 1984)

Trees

- A more-or-less continuous canopy stratum, above it a discontinuous stratum ('emergents').
- A discontinuous small-tree stratum.
- A rich array of species.
- Leaf-sized, small, mainly microphyll.

Climbers

- Large woody climbers are common and diverse.

Epiphytes

- Large epiphytes may be either rare or common, but there are few species.

Special features

- Mosses and ground ferns rare, no tree-ferns, prickly shrubs common.

Habitat

- Warm areas with fairly low average annual rainfall (600–1100 mm).

Floristics

- A small number of emergent species occur; they include the lace-bark tree, *Brachychiton discolor.*
- The canopy and small-tree strata are often dominated by species of a few families, particularly (in the Hunter Valley) Euphorbiaceae and Sapindaceae.

chances of arrival and establishment of disseminules at individual stands (the past supply of disseminules being assumed to be at a maximum close to the coast at a time-scale of centuries, millenia and longer).

Abundances and inter-stand frequencies considered together

Centrally important features of forest vegetation are the floristic composition of the tree strata and the relative abundances of the species, especially in the main canopy layer. In Table 11 attention is concentrated on those tree species assessed as abundant (VC or C) in most of the stands. The twelve most successful species in this sense are arranged in the Table in decreasing order of inter-stand frequency. Some of these trees do not normally reach the canopy stratum of the forest. Information from Floyd (1989) on tree heights is presented in the right hand column of the Table. In the Hunter Valley, *Cleistanthus cunninghamii*, *Croton verreauxii*, and *Claoxylon australe* are not tall enough to be counted as members of the canopy stratum. The eight other species in the list can be included as well, although some of them, such as *Streblus brunonianus* and *Elattostachys nervosa*, often reach only the lower part of the canopy. In terms of its consistently high abundance, *Streblus* is clearly in a class by itself. Further down the list, there are large gaps in inter-stand frequency (in the VC + C column) below *Capparis arborea* and below *Croton verreauxii*.

The three species most often noted as emergents in the stands examined are also listed in Table 11: *Brachychiton discolor*, *Ficus macrophylla* and *F. superba* var. *henneana*. It is a characteristic of the emergents that they are rarely present in large numbers in a stand — examination of Table 11 shows that their (O + R) inter-stand frequencies are much greater than their (VC + C) inter-stand frequencies.

Table 10. List of those species showing large (≥ 20%) inter-stand frequency differences between E and C + W sectors

E>> (C + W)	(C+ W) >> E
Trees (total spp = 95)	
Alangium villosum	*Scolopia braunii*
Actephila lindleyi	*Toona australia*
Citronella moorei	*Austromyrtus acmenioides*
Pennantia cunninghamii	*Backhousia myrtifolia*
Backhousia sciadophora	*Pittosporum undulatum*
Melicope micrococca	*Podocarpus elatus*
Elattostachys nervosa	*Sarcomelicope simplicifolia*
Celtis paniculata	
Dendrocnide photinophylla	
(n = 9)	(n = 7)
Shrubs (total spp = 17)	
Pittosporum revolutum	
Spartothamnella juncea	
**Lantana camara*	
(n = 3)	
Herbs (total spp = 25)	
Alocasia macrorrhizos	*Pseuderanthemum variabile*
Gymnostachys anceps	*Plectranthus parviflorus*
Lastreopsis microsora	*Viola hederacea*
Pollia crispata	
(n = 4)	(n = 3)
Climbers (total spp = 40)	
Parsonsia velutina	*Passiflora herbertiana*
Gymnema pleiadenium	
**Delairea odorata*	
Pandorea pandorana	
Diosscorea transversa	
Austrosteenisia blackii	
Stephania japonica	
**Passiflora subpeltata*	
Piper novae-hollandiae	
Morinda acutifolia	
(n = 10)	(n = 1)
Epiphytes/lithophyytes (total spp = 23)	
Asplenium attenuatum	
Asplenium australasicum	
Dendrobium speciosum	
Dendrobium teretifolium	
Peperomia leptostachya	
Platycerium sperbum	
(n = 6)	(n = 0)

Notes. Eastern sector (E) : 18 stands; Central (C) and Western (W) sectors : 25 stands. (A total of 43 stands; reduced from the 46 stands of Appendix 1 because of some consolidation of species lists — see notes accompanying Appendixes 2 and 3.) - Within each structural category, the genera are arranged in the same (family-ordered) sequence as that in which they occur in Appendixes 2 and 3. – * denotes a naturalised species.

Attention has been given so far to those tree species which are both most frequent across stands and most abundant within stands. The situation in the other structural groups must now be briefly examined. Table 12 lists in decreasing order, in the same way as Table 11, those species with the highest inter-stand frequencies in each group. The results provide agreement with that part of the description of dry rainforest set out in Table 9 concerning the general sparseness of Herb (mostly ferns) and

Table 11. Most frequent and abundant tree species

Species	Inter-stand frequencies (%) in the following intra-stand abundance categories:* VC+C	O+R	Total	Tree height (m) (Floyd 1989)
Trees with the highest VC + C frequencies				
Streblus brunonianus	98	2	100	30
Mallotus philippensis	84	14	98	25
Capparis arborea	81	19	100	10
Baloghia inophylla	65	35	100	25
Olea paniculata	60	28	100	30
Dendrocnide excelsa	58	35	93	40
Cleistanthus cunninghamii	53	28	81	9
Drypetes australasica	53	21	74	25
Croton verreauxii	49	51	100	20
Elattostachys nervosa	33	51	84	30
Claoxylon australe	32	63	95	9
Geijera salicifolia var. *latifolia*	26	67	93	30
Trees often present as emergents				
Brachychiton discolor	11	77	88	30
Ficus macrophylla	2	56	58	50
Ficus superba var. *henneana*	0	65	65	35

* Abundance information drawn from the full range of data (43 stands) set out in Appendixes 2 and 3.
VC : Very common, C : Common, O : Occasional, R : Rare, very infrequent

Epiphyte/Lithophyte groups. Here too the same comment can be applied to the Shrub group. In all three groups, for almost all the small number of species involved, there are few stands where abundances are high. In contrast, the success of the Climber group is apparent, particularly large woody climbers. All of the eight listed climbers are woody and of them only *Legnephora moorei* does not attain large stem diameters.

So far those species have been emphasised which are both frequent and abundant. Obviously, other categories could also be considered. We shall look briefly at only one group: tree species of high inter-stand frequency but of consistently low abundance. Table 13 is organised in a way similar to Table 11 — it lists, in decreasing order, the 16 tree species with the highest inter-stand frequencies of O and R abundances.

This information serves to point up the richness of the tree flora in the dry rainforest of the Hunter Valley. These sixteen species take us down to a frequency of 70%, still relatively high — there are many other species as well with lower frequencies. The listed species range from tall trees down almost to shrubs — as a group, they are most important in helping to fill the top three strata of the forest with populations successful in terms of their spread amongst stands but rarely large locally.

To emphasise the point that some tree species seem never to be abundant in individual stands, Table 13 lists separately (with some repetition from the main part of the Table) those six species having, at the same time, the highest O and R frequencies and zero frequencies in the VC + C abundance categories.

Table 12. Shrub, herb, climber and epiphyte/lithophyte species with the highest inter-stand frequencies and high intra-stand abundances

Species	Inter-stand frequencies (%s) in the following intra-stand abundance categories:* VC + C	O + R	Total
Shrubs with the highest VC + C frequencies			
Citriobatus pauciflorus	97	0	97
*Lantana camara***	63	14	77
Abutilon oxycarpum	14	58	72
Herbs with the highest VC + C frequencies			
Adiantum formosum	56	37	93
Pellaea falcata var. *falcata*	42	56	98
Doodia aspera	38	57	95
Adiantum aethiopicum	29	67	96
Pellaea falcata var. *nana*	19	71	90
Climbers with the highest VC + C frequencies			
Cissus antarctica	98	2	100
Parsonsia straminea	77	23	100
Tetrastigma nitens	77	23	100
Austrosteenisia blackii	56	12	68
Legnephora moorei	47	47	94
Pandorea pandorana	35	65	100
Malaisia scandens	30	56	86
Jasminum volubile	30	42	72
Epiphytes and Lithophytes with the highest VC + C frequencies			
Pyrrosia confluens	38	60	98
Dendrobium speciosum	7	64	71
Asplenium australasicum	5	40	45

* Abundance information as for Table 11.

** An introduced species, now naturalised.

Species numbers in individual stands

Table 14 presents total observed species numbers as well as statistics of numbers of species per stand for each of the structural groups. Some comparable data from other Hunter Region rainforest studies are also included. The figures serve to emphasise once again the richness of these dry rainforest stands in woody plants, especially trees and vines, in agreement with the broad description given in Table 9. The stands of warm-temperate rainforest studied by Gambrill (1986) occur on the south-western margin of the Hunter Valley and are notably poor in species.

Within a particular region, what measures might be used to predict the floristic richness of individual stands? It is reasonable to expect that stand area (as a crude measure of relative habitat diversity) will be positively associated with species numbers. Another stand characteristic which might also be expected to be directly related to habitat diversity is altitudinal span. Assuming that the coastal belt of the

Table 13. Tree species with high inter-stand frequencies and low intra-stand abundances

Species	Inter-stand frequencies (%s) in the following intra-stand abundance categories:*			Tree height (m) (Floyd, 1989)
	O+R	VC+C	Total	
Trees with the highest O + R frequencies				
Hibiscus heterophyllus	91	9	100	6
Notelaea longifolia	91	7	97	9
Clerodendrum tomentosum	88	2	91	15
Cassine australis	86	9	95	8–9
Scolopia braunii	81	0	81	25
Alphitonia excelsa	79	5	84	35
Alectryon subcinereus	79	14	93	18
Elaeocarpus obovatus	77	9	86	45
Toona ciliata	74	5	79	45
Pararchidendron pruinosum	74	0	74	15
Diploglottis australis	74	12	86	35
Ficus rubiginosa	72	5	77	30
Diospyros australis	70	16	88	20
Dysoxylum fraserianum	70	16	86	55
Hymenosporum flavum	70	2	72	20
Melicope micrococca	70	0	70	35
Trees with the highest O + R frequencies and with zero VC + C frequencies				
Scolopia braunii	81	0	81	25
Pararchidendron pruinosum	74	0	74	15
Melicope micrococca	70	0	70	25
Guioa semiglauca	67	0	67	18
Polyscias elegans	67	0	67	30
Wilkiea heugeliana	58	0	58	8

* Abundance information as for Table 11.
VC : Very common, C : Common, O : Occasional, R : Rare, very infrequent

Hunter Valley has been the main local source of lowland rainforest species over long periods (kept supplied by northward and southward migrations along the east coast of the continent), then the distance of a stand from the coast may be an inverse measure of the relative accessibility of that stand to disseminules. Present average annual rainfall is an environmental variable which may have both direct (moisture supply to individual plants) and indirect (an influence on stand size and hence on habitat diversity) effects.

These considerations provide no more than a very rough basis for a search for possible associations between species numbers and landscape variables of various kinds. The complexity of the situation derives in part from unknown but continuing influences of climatic regimes of the past. Product-moment correlation coefficients have been calculated in turn between species numbers per stand in the various structural groups and the variables mentioned above. Another variable has also been incorporated: the overall slope angle of individual stands (Table 15).

Three or more correlation coefficients designated as significantly different from zero occur for each of the stand characteristics, area, slope angle and altitudinal span

Table 14. Species* numbers in the surveyed stands of dry rainforest and other rainforest types in the Hunter region

	Structural Group					
	Trees	**Shrubs**	**Herbs**	**Climbers**	**Epiphytes/ Lithophytes**	**Total**
The present survey						
Total spp numbers across all surveyed stands	95	13	25	37	23	193
Total spp numbers in the Eastern stands	88	11	24	37	20	180
Total spp numbers in the Central and Western stands combined	88	12	25	33	18	176
Range	32–71	3–9	6–20	9–32	1–16	64–144
Median	45	5	12.5	19	6	88
Mean	47.4	5.4	12.2	18.9	6.4	90.6
Standard deviation (±)	8.7	1.5	3.3	4.3	3.4	17.6
Coefficient variation (%)	18	28	27	23	53	19
Numbers of stands included	43	43	42	43	42	42
Other local studies						
Total spp numbers across all surveyed stands:						
• Liverpool Ra: warm-temperate rainforest (Fisher 1980)	35	16	26	20	12	109
• Wollemi basalt caps: warm-temperate rainforest (Gambrill 1986)	9	7	ND	6	ND	ND

* Only native species (but not eucalypts, grasses or sedges) included.
ND : Not determined

against species numbers. The strongest and most numerous of these associations occur in the case of stand area: all the plant structural groups except herbs are involved. The association between species numbers and slope angle is not as strong and is negative: the steeper a stand, the fewer species it tends to have, especially trees. The association between species numbers and altitudinal span is a positive one but it occurs only with the subsidiary structural groups, not trees. Contrary to our expectation, distance from the coast has no pronounced association with species numbers, and for average annual rainfall there is only one significant association (with climbers).

The basic assumptions of normality of variate distribution and randomness of sample selection should apply to the data on which Table 15 is based just as in any other

Table 15. Product-moment correlation coefficients between species numbers in stands of dry rainforest and some physical characteristics of stands

Stand Characteristics	Structural Group (Species numbers per stand)							
	Trees	Shrubs	Herbs	Climbers	Epiphytes/ Lithophytes	Trees+ shrubs	Trees+ shrubs+ vines	Total
Altitudinal span	0.111	0.367*	0.365*	0.331*	0.222	0.167	0.240	0.268
Area	0.500**	0.298*	0.295	0.390**	0.595**	0.522**	0.525**	0.537**
Average annual rainfall	0.012	0.013	0.258	0.358*	0.190	0.013	0.135	0.176
Distance from coastline	-0.086	0.135	0.030	-0.225	-0.275	-0.058	-0.122	-0.145
Slope angle	-0.399**	0.074	-0.366*	-0.185	-0.338*	-0.365*	-0.337*	-0.380*
Sample size	43	43	42	43	42	43	43	42

* Correlation coefficient significantly different from 0, $p \leq 0.05$. ** Correlation coefficient significantly different from 0, $p \leq 0.01$.

significance testing of a parametric type. In fact, however, both assumptions must be regarded as being no more than roughly fulfilled in the present case (a common feature of field ecological analysis), and interpretation of results should accordingly be very conservative. The reader will recall also that the data themselves have some uncertainties: it was pointed out earlier that the species numbers are very likely to be under-estimates, and under-estimates in varying degrees, of the true values (see Table 1). The stand measures employed are probably no better than crude surrogates for the critical (but unknown-in-detail) environmental and historical controls.

Two of the stands, Mirari Creek (C6) and Pilchers Mountain (C8), are particularly rich in species. The species lists for both stands (Appendix 2) are composites of visits by Floyd (1983a) and by Vernon in this present survey. However, we are of the opinion that, despite this double sampling, the observed richness is real compared with other stands. Both of them lie on the Wallarobba Range, near the eastern side of the survey area, and each seems to have a considerable amount of internal heterogeneity of topography. However, neither is unique in this respect and we are unable to offer a convincing explanation of their extreme richness.

Distribution patterns of individual species

Species at their southern limits

Eleven rainforest species — five trees, one herb and five climbers — are considered to be at their southern limits within the survey area (Table 16). Our survey has changed only slightly, and then not for all of the listed species, the limits established by Floyd (1983a, 1989). The new limits should be regarded as no more than provisional — continuing reconnaissance frequently leads to expansion of the known ranges of plants.

The latitudinal span of the known southern limits of these eleven species is about 16.5 minutes or 30.5 km, extending from Tabbil Ck (Stand E10, at 32° 24.7' S) to Comerfords Hill (at 32° 41.2' S — centre of stand: grid reference 654 825, Maitland 1:25 000 map sheet).

The distributions of selected species across the surveyed stands

It is feasible here to plot the observed distribution of only a small number of the species encountered in the survey. The distribution patterns of the three emergents having the highest inter-stand frequencies (*Brachychiton discolor*, *Ficus macrophylla* and *F. superba* var. *henneana*) are presented in Figure 4. Within the survey area, *Brachychiton discolor* is at its known southern limit. Included in Figure 5 is another southern-limit species, *Backhousia sciadophora*. Figure 5 also shows the patterns of occurrence of a further two trees of restricted local distribution (*Canthium copmosmoides* and *Podocarpus elatus*) and also of the locally-widespread weed, *Lantana camara*.

The three emergents mapped in Figure 4 are fairly consistently absent from the peripheral stands of those examined in the survey area. In two stands, E17 on the northern side and C2 on the southern side, none of the emergents was seen, and in other peripheral stands, only one of the three species was noted. We consider that the presence of emergents is an indication of dry rainforest in the Hunter Valley in its most mature and complex form. Those peripheral stands without emergents usually

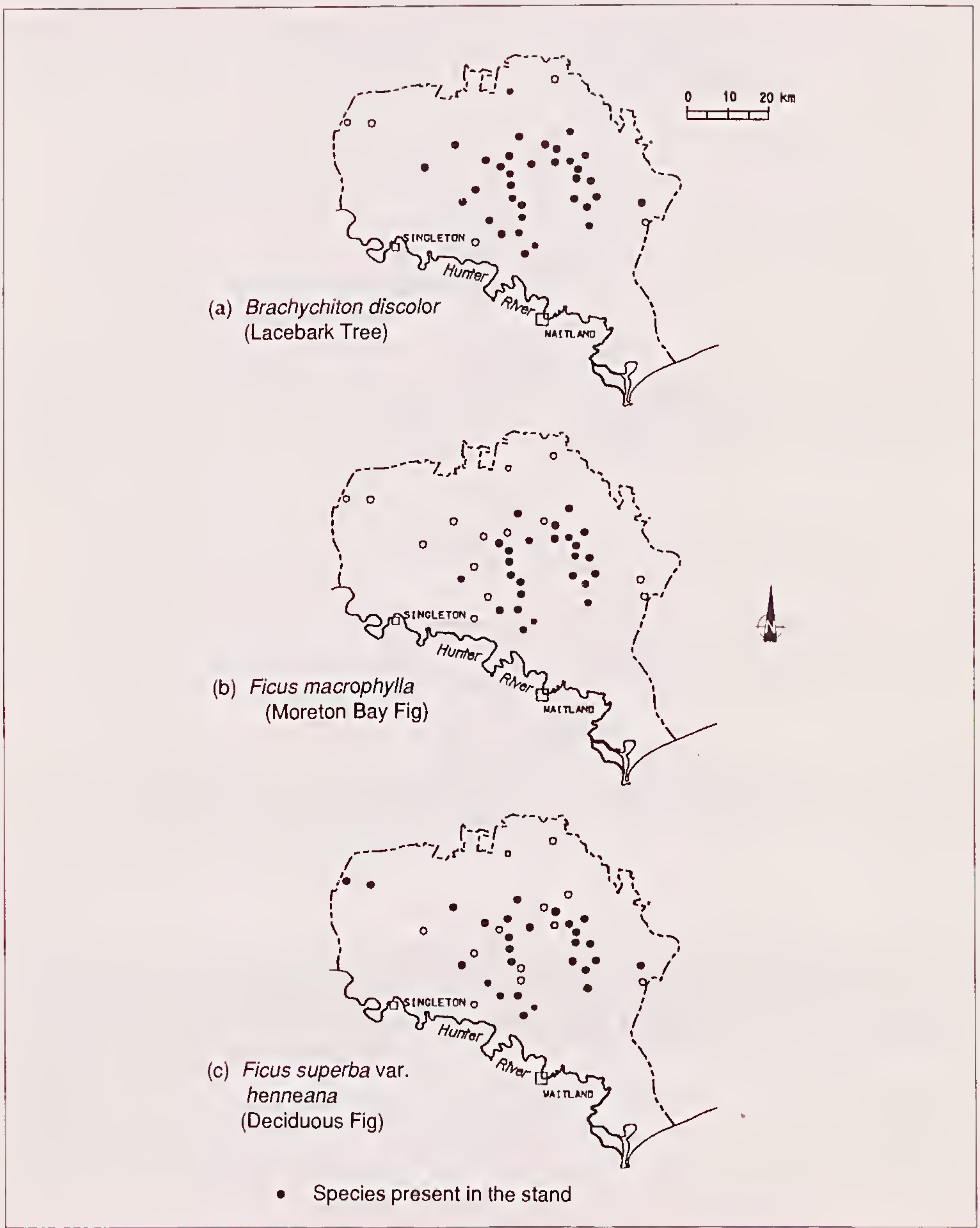
Table 16. Species with known southern limits in the dry rainforest stands of the survey area

Species	Southern limits previously observed	New limit
Trees		
Backhousia sciadophora	Mirari Ck, Mt Ararat (E6) (Floyd 1989)	Mt Douglas (E1)
*Brachychiton discolor**	Paterson (probably Moonabung Falls) (Floyd 1989)	Kilfoyles Ck
*Cleistanthus cunninghamii**	Moonabung Falls (C1) (Floyd 1989)	Comerfords Hill
Dysoxylum rufum	Bulahdelah and Williams R (Floyd 1989)	Tabbil Ck (E10)
Elattostachys nervosa	Paterson (probably Moonabung Falls) (Floyd 1989)	Moonabung Falls (C1)
Herbs		
Tripladenia cunninghamii (=*Kreysigia multiflora*)	Bulahdelah (Rotherham et al. 1975)	Rosewood Gully (C2)
Climbers		
Cayratia eurynema	Pilchers Mountain (E8) (Floyd 1983a)	(Not observed in present survey)
*Gymnema pleiadenium**	Pilchers Mountain (E8) (Floyd, 1983a)	Moonabung Falls (Chalmers & Turner, 1994)
*Marsdenia suberosa**	Mirari Ck, Mt. Ararat (E6) (Floyd 1983*a*)	Comerfords Hill
Morinda acutifolia	Moonabung Falls (C1) (Floyd 1983a)	Moonabung Falls (C1)
Parsonsia velutina	Moonabung Falls (C1) (Floyd 1983a)	Moonabung Falls (C1)

* Limits determined since the survey was completed. The Kilfoyles Ck stand is 4 km south-west of Moonabung Falls. Comerfords Hill is a bluff on the northern bank of the Hunter River, about 11 km south–south-east of Moonabung Falls.

possess other characteristics of dry rainforest, of course, such as an abundance of woody climbers of certain species and an array of many of the typical tree species. It is of interest that even the two most westerly stands, W1 and W2, are not without one of the three emergents referred to in Figure 4, *Ficus superba* var. *henneana* in this case.

Two tree species showing marked tendencies to east-west localised distributions are *Podocarpus elatus* and *Backhousia sciadophora* (Figure 5). *Podocarpus elatus* was observed only in the Central sector and *B. sciadophora* only in the Eastern sector, mainly on the



(a) *Brachychiton discolor* (Lacebark Tree)

(b) *Ficus macrophylla* (Moreton Bay Fig)

(c) *Ficus superba* var. *henneana* (Deciduous Fig)

Figure 4. Maps of the observed occurrence of three emergent tree species amongst the surveyed stands. Because of the scale used, it has been judged necessary to merge some closely contiguous stands.

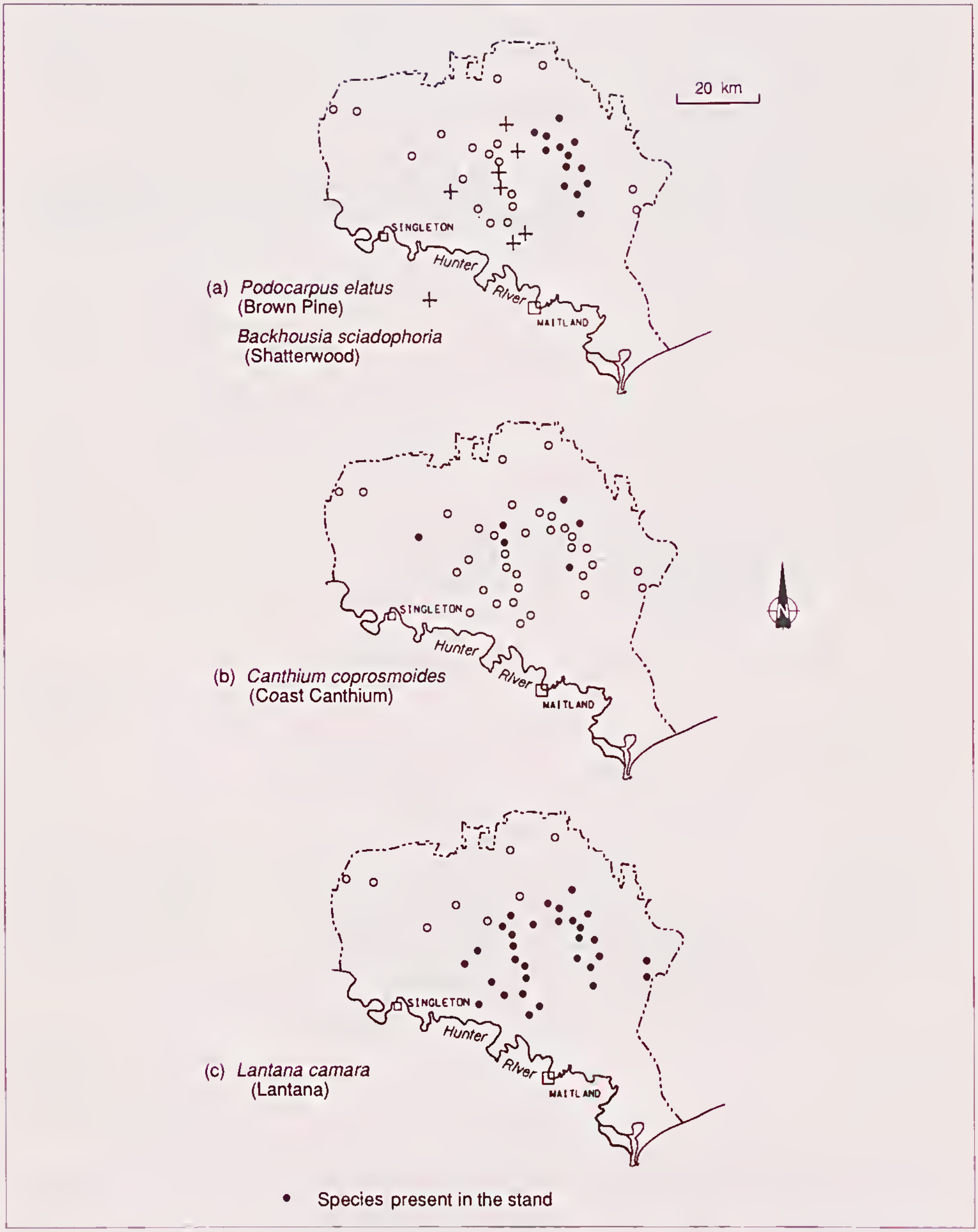

20 km
SINGLETON
Hunter River
MAITLAND
(a) *Podocarpus elatus* (Brown Pine)
+ *Backhousia sciadophoria* (Shatterwood)
(b) *Canthium coprosmoides* (Coast Canthium)
N
(c) *Lantana camara* (Lantana)
• Species present in the stand

Figure 5. Maps of the observed occurrence of three tree species and the shrub/scrambler, *Lantana camara*, amongst the surveyed stands. Because of the scale used, some closely contiguous stands have been merged.

Wallarobba Range. In contrast, *Canthium coprosmoides* occurs in both Eastern and Central sectors, seemingly becoming more restricted in its distribution towards the west. The westernmost stand in which it was seen, C18, is 63 km from the nearest coast, unexpectedly far given the tree's common name of Coast Canthium and its usually-recorded distribution (Floyd 1989) in near-coastal sites.

The weed *Lantana camara* is widespread as well as abundant in Eastern and Central stands (Figure 5), but clearly there are limitations to its occurrence to the north and west. To the north (stands E17 and C21), low temperatures are most likely limiting, to the west moisture supply is probably critical. There is a possibility too that the species has not yet fully occupied its potential range here and that it may still be moving, albeit slowly, to north and/or west. However, this idea must be considered unlikely given the species' long presence in NSW and its proven mobility in other coastal areas.

Broad-scale occurrences in rainforest types of the listed tree species

Vernon (1985) tried to distinguish between those tree species unmistakably of dry rainforest and those of sub-tropical rainforest. She found that there was by no means complete agreement between the authorities, Floyd (1960–1982, 1983a & b, 1984) and Williams (1975–1980, 1982), as to which was which. She commented on page 57:

> The criteria for classifying species in this way appear to be vague and are based largely on the experience of both Floyd and Williams ... There are as yet no objective guidelines by which to decide whether a species can more appropriately be classed as subtropical or dry. Therefore attempts to identify gradations from one rainforest subform to another, both within each study stand and from one stand to another, will necessarily be somewhat arbitrary and subjective.

We decided to use Floyd (1989) as the latest authority, to examine the broad-scale occurrence across the various rainforest types of the tree species observed in our survey (Table 17). We have combined some of Floyd's categories of individual rainforest types. Ninety-one tree species are included. Of those listed in Appendixes 2 and 3, the following were excluded:

1. those whose main occurrences are not in rainforest (*Brachychiton populneus, Casuarina cunninghamiana, Melaleuca quinquenervia* and *M. styphelioides*)

2. those with some claim to being of rainforest affinity (ecologically and/or taxonomically) but which are not dealt with in Floyd's book (*Geijera parviflora, Hymenanthera dentata* and *Notelaea microcarpa* var. *microcarpa*).

Based on Floyd's assessment, more than half of the tree species referred to in Table 17 are wide-ranging in their occurrence in rainforest in NSW. Their cosmopolitan presence does not impose any distinctive character on the stands examined. However, also present are twenty-three species whose main occurrences are in dry rainforest, and it is these which firmly place the surveyed stands in the dry rainforest category. Numbers in the remaining groups are small and show only a minor presence of sub-tropical- and warm temperate-favouring species. Nevertheless, although the modal class of average annual rainfall of these stands is only 800–899 mm, the tree floral list covers a wide range of preferred rainforest types — it is a very mixed assemblage, missing only species which prefer cool temperate rainforest. As a confirmation of the prevailing dry rainforest character of the stands, all of the twelve most abundant and frequent tree species of the survey (Table 11) occur in the left-hand half of Table 17, i.e. the 'dry and wide-ranging' side.

Cluster analysis of the stands

A dendrogram showing fusion sequences is set out in Figure 6. Only the final fourteen groupings have been retained for the figure — examination of smaller clusters did not yield any noticeable increase in interpretability in ecological or geographical terms.

Table 17. Assignment of the observed rainforest tree species to the broad rainforest types recognised by Floyd (1989)

GROUPINGS OF RAINFOREST TYPES

Dry Rf alone	Dry Rf ± Littoral Rf ± Riverine Rf	Wide-ranging across all or most types	Sub-tropical Rf and Dry RF ± Littoral Rf ± Riverine Rf	Sub-tropical Rf ± Gully Rf ± ± Littoral Rf Riverine Rf	Sub-tropical Rf and Warm-temperate Rf ± Riverine Rf	Warm-temperate Rf ± Littoral Rf	Riverine Rf and/or Rf margins
NUMBER OF SPECIES (Total: 91)							
11	12	50	3	5	6	2	2
*Croton verreauxii**	*Capparis arborea**	(The top 12 spp. of 50 spp.)	*Dendrocnide excelsa**	*Dysoxylum fraserianum*	*Toona ciliata*	*Cryptocarya microneura*	*Glochidion ferdinandi*
Brachychiton discolor	*Hibiscus heterophyllus*	*Streblus brunonianus**	*Sarcomelicope simplicifolia*	*Daphnandra micrantha*	*Citronella moorei*	*Stenocarpus salignus*	*Tristaniopsis laurina*
*Cleistanthus cunninghamii**	*Cassine australis*	*Baloghia inophylla**	*Ehretia acuminata*	*Brachychiton acerifolius*	*Pennantia cunninghamii*		
Ficus rubiginosa	*Alectryon subcinereus*	*Mallotus philippensis**		*Podocarpus elatus*	*Emmenosperma alphitonioides*		
Austromyrtus acmenoides	*Olea paniculata**	*Notelaea longifolia*		*Symplocos thwaitesii*	*Rapanea howittiana*		
Backhousia sciadophora	*Drypetes australasica**	*Claoxylon australe**			*Cinnamomum oliveri*		
Alchornea ilicifolia	*Rhysotoechia bifoliolata*	*Geijera salicifolia**					
Croton insularis	*Melia azedarach*	*Clerodendrum tomentosum*					
Maytenus sylvestris	*Ficus superba*	*Diospyros australis*					
Codonocarpus attenuatus	*Canthium coprosmoides*	*Planchonella australis*					
Canthium odoratum	*Myoporum acuminatum*	*Diploglottis australis*					
	Ficus fraseri	*Elaeocarpus obovatus*					
		*Elattostachys nervosa**					

* The 12 most abundant and frequent species, as listed in Table 11.

Table 18. Stand characteristics of some of the clusters delineated in Figure 6

Cluster (refer to Figure 6)	**Number of stands**	**Area of stand (ha)**		**Number of tree species/stand**	
		Mean	±Standard deviation	Mean	±Standard deviation
Western stands*	5	10.6	±6.9	42.6	±3.6
Northerly stands and rich and large stands	12	32.2	±19.6	56.8	±9.1
Mostly Central sector stands	13	16.2	±15.5	42.9	±4.8
Mostly Eastern sector stands	13	15.8	±15.4	45.2	±5.2

* Exclusive of Wg data, for which there is no single stand area.

Of the two large groups defined before the final fusion, the one on the left side consists of more readily interpretable sub-groups than that on the right side. The six most westerly of the stands are clearly separated from all others in terms of floristic similarity. Then, the most northerly stands occur together but are close to what we term 'rich (in tree species) and large (in area)' stands. The reason why these latter two sub-groups should be closely similar is not clear to us.

On the right side of the dendrogram, we can detect only what seems to be a trend, rather than a clear-cut demarcation of stands with particular characteristics within the sub-groups. The sub-groups on the left consist of more Central sector stands than Eastern (eight to five), while the tendency is exactly reversed in the sub-groups on the right. A look at some stand characteristics across sub-groups of the dendrogram (Table 18) shows that there are no great differences between those on the right side but that the stands of the 'rich and large' sub-group (combined with the three northerly stands) are markedly richer and larger on average than the stands of other sub-groups.

Overall, this analysis, as far as it has been taken, indicates that most stands in the Central and Eastern sectors form a large group which is not readily differentiated into sub-groups on ecological or geographical bases. The stands separated in floristic similarity from this large group are those which occur on the western and northern peripheries of the surveyed area and some of those which are richest in tree species and relatively large in area.

Results

c) Human influences

General observations on disturbance

There seems to be no broad-scale clearing — nor timber-getting — going on any longer in the rainforest stands of the survey area. However, many cases were seen where rainforest has been damaged by track-making activities. Sometimes, too, the best or only remaining eucalypt stems (used for fence posts) remaining on a property are at the edges of rainforest stands and logging tracks may be put in without thought to damage being done to the stand itself.

Another way in which direct damage can occur is as a result of epiphyte collection. The edges of some of the surveyed stands seem to be particularly prone to this kind

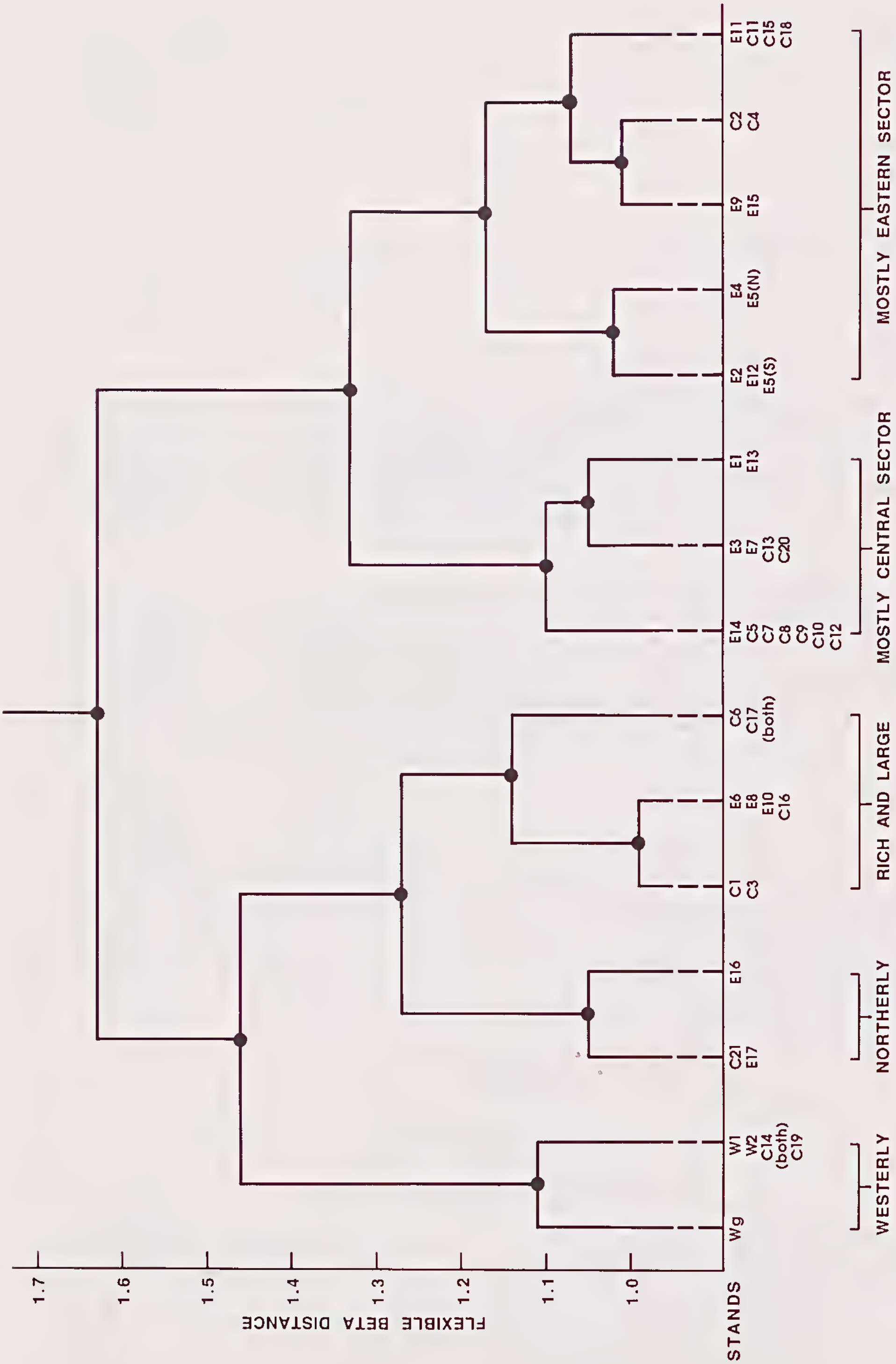


Figure 6. Dendrogram of groups of stands resulting from flexible-beta clustering procedure. Beta = −0.25.

of disturbance, probably because of their closeness to one or other public roads. In a few cases, trees were seen (particularly *Dendrocnide excelsa*, Giant Stinging Tree) which had probably been felled for their load of epiphytes.

Fires are often lit in hill pastures in this area, particularly in early spring, to encourage the rapid growth of new grass. Such fires seldom or never penetrate to the central parts of rainforest stands — however, by burning up to the edges of stands, they may cause the death of many rainforest seedlings and saplings. It is possible that the changed fire regime since white settlement has on balance been more damaging to rainforest edges than the pre-settlement regime.

Cattle seem not to browse on most rainforest plants — at least on those older than saplings — but they trample soils and plants, particularly at the edges of stands. Cattle tend to use the edges of stands for shelter — in a small stand, this may mean that no part of the stand is free of the disturbance resulting from trampling and the concentration of droppings.

Finally, there is the presence of the weed *Lantana camara* in and around most of the stands in the eastern half of the survey area (it occurred in three-quarters of the surveyed stands). The light requirements of *Lantana* are such that it is most successful around the edges of stands and below canopy gaps. The danger from such a vigorous competitor is that, over decades and longer, it will begin to diminish seriously the regeneration success of native species, especially of the rarer ones. Its long-term effect may well be to reduce the diversity of individual stands, and perhaps even to cause some local extinctions of rainforest species.

The condition of stand margins

Past forest-clearing activities have turned most of the survey area into a grassland in which scattered eucalypt trees remain. In this altered landscape, the margins of many rainforest stands now abut directly on to pasture. A stand margin in this situation must be regarded as being more at risk from potential disturbance than one where a belt of open-forest remains to act as a buffer. All of the surveyed stands were examined from this point of view, using both the sketch maps prepared at the time of ground survey and colour transparencies from plane flights. A sequence of five categories of relative 'protection' of stand margins by eucalypts was defined and each of the forty-six stands was assigned to a category (Table 19).

This examination indicates that most of the surveyed stands still have at least some contact at their margins with remnants of eucalypt-dominated open-forest. Indeed, most stands have fairly substantial buffer zones of eucalypts. There is a need for study of the whole subject of the pattern and condition of fragments of open and closed forests in this area in relation to effective plant and animal conservation.

Discussion

Botanical features

The surveyed stands form a fairly homogeneous unit within the dry rainforest subformation. Cluster analysis showed that there is some tendency to differentiation, especially on the western and northern peripheries of the survey area — however, it seems not to be strongly pronounced.

The total area of the forty-six surveyed stands is some 850 ha, with a median stand area of 15 ha. Some hundreds of other stands were not examined. This broad sweep

Table 19. Summary of extent of occupation by eucalypts of the margins of the surveyed rainforest stands

Eucalypt occupation of stand margins*	% of Stands in each category			
Stands	Eastern Sector	Central Sector	Western Sector	All stands
(1) None	0	8	0	4
(2) Narrow eucalypt fringe along < half of periphery	30	12	50	22
(3) Narrow eucalypt fringe along ≥ half of periphery	15	17	50	17
(4) Substantial eucalypt stand along < half of periphery	25	33	0	28
(5) Substantial eucalypt stand along ≥ half of periphery	30	29	0	28
	100	99	100	99
Total number of rainforest stands assessed	20	24	2	46

* Further description of the categories:
(1) No more than occasional isolated mature eucalypts on stand margin.
(2) and (3) Continuous fringe of mature eucalypts, but no more than 25 m wide.
(4) and (5) There is an adjoining mature eucalypt stand which is at least 100 m wide and which has an area of at least 1 ha. There may or may not be, as well, fringing eucalypts of categories (2) or (3).

of stands in the Hunter Valley is the southernmost occurrence in Australia of a substantial area of floristically and structurally well-developed dry rainforest. There are elements of this rainforest type as far south as the South Coast of NSW, but they are much attenuated in extent, composition and complexity compared with the stands in the Hunter Valley. An illustration of this attenuation can be found in the southern limits of some of the tree species important in Hunter Valley stands. Those five 'abundant and frequent' trees identified in Table 17 as being known to be predominantly dry rainforest species (i.e. from the two columns at the left hand side of that table), are important in imposing a dry rainforest identity on the stands in the Hunter Valley (as well as on stands further north). Of these species, only *Croton verreauxii* has its southern limit outside the Hunter Valley. Together with *Brachychiton discolor,* also a dry rainforest species and the emergent tree with the highest inter-stand frequency in the surveyed stands, the other species have their limits within the survey area or immediately to the south of it (Floyd 1989).

Conservation considerations

None of the species listed in Appendixes 2 and 3 is on the rare or threatened plants list of Briggs and Leigh (1988). The main concern in conservation terms is that as many stands as possible in the survey area should remain structurally and floristically intact in the long term. At present the prognosis is not favourable because almost all the surveyed stands are on freehold land. The main exception is a part of Stand E8, Pilchers Mountain, which is a Crown Reserve for Recreation and which has already been recommended for Nature Reserve status by Floyd (1983a). From his limited survey, Floyd also recommended as worthy of conservation the Moonabung Falls (C1) and Cabbage Brush Creek stands (the latter is 4.5 km north-north-west of Moonabung Falls). Clearly, many other stands are worthy of protection and the current conservation status of the remaining rainforest across the survey area is highly unsatisfactory.

Fortunately, however, there is a clearly discernible trend amongst land-owners for the development of a sense of long-term care for the welfare of their land. Many of the owners encountered during the survey expressed great interest in the stands under survey. We believe that lack of specialised knowledge and advice, as well as a lack of financial incentive from governments, often inhibits conservation action by landowners. The recent growth of the Land Care movement is a welcome development from this point of view.

Within the survey area at present, the situation pertaining to the care of eucalypt-dominated open-forest is as unsatisfactory as that for dry rainforest. An ecologically-attractive possibility would be the planned conservation of tracts containing the two vegetation types in contact with each other, each in good condition. The notion of the value of a eucalypt forest buffer around the margin of a rainforest stand was raised earlier. Clearly, the idea could be extended so that appropriately-located examples of foothill eucalypt forest could be conserved in their own right. The preservation of a network of side-by-side residual stands of the two forest types across a broad sweep of country is an ideal to aim at.

Acknowledgements

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Appendix 1. Information about the stands: location and some physical features

EASTERN SECTOR

Code designation	Stand name	Map sheet (1: 25 000) and grid reference	Area of stand (ha)	Altitudes of upper and lower margins (m)	Topographic type
E1	Mt Douglas	Paterson, 748 992	6	130–240	Down-stream valley site
E2	Glen Martin	Clarence Town, 909 004	2.5	50–140	Single gully-head
E3	Stony Creek, Wallarobba	Gresford, 750 043	17	100–210	Weakly-gullied rocky slopes
E4	Three Brothers: North Face	Dungog, E Stand: 893 040 W Stand: 895 040	E Stand: 4 W Stand:	110–170 80–160	Both stands: gully-head amphitheatres
E5	Three Brothers: Small Hill to North	Dungog, N Stand: 898 049 S Stand: 898 046	N Stand: 2 S Stand: 3	110–210 60–120	N Stand: gully-head amphitheatre S Stand: single gully-head
E6	Mirari Creek, Mt Ararat	Gresford, 725 055	19	100–240	Down-stream valley site
E7	Wallaringa Rd	Gresford, 771 071	8	180–230	Weakly-gullied rocky slopes
E8	Pilchers Mountain	Gresford, 765 100	32	230–350	Gully-head amphitheatre
E9	Coxs Gully	Gresford, 735 109	40	170–250	Down-stream valley site
E10	Tabbil Creek	Gresford, 737 131	84	170–430	Multiple gully-heads
E11	Wallarobba Range: West Side	Gresford, 734 143 (point central to both stands)	N Stand: 28 S Stand:	120–360 120–320	Both stands: multiple gully-
E12	Bingleburra	Gresford, 676 145	9	90–230	Single gully-head
E13	Wallarobba Range: NE Section	Gresford, 741 155	67	150–310	Multiple gully-heads
E14	Lewinsbrook	Gresford, 675 171 (at junction of Gresford and Allynbrook sheets)	21	120–330	Single gully-head
E15	Dog Trap Creek	Allynbrook, 668 175	19	130–370	Single gully-head
E16	Brandy Creek	Allynbrook, 706 219	23	170–370	Multiple gully-heads
E17	Chichester Gap	Chichester, 678 346	38	220–530	Multiple gully-heads

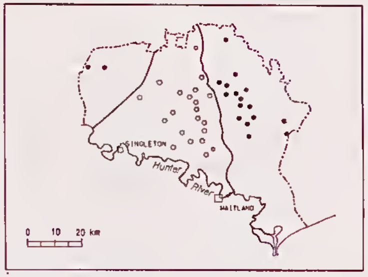
CENTRAL SECTOR

Code designation	Stand name	Map sheet (1: 25 000) and grid reference	Area of stand (ha)	Altitudes of upper and lower margins (m)	Topographic type
C1	Moonabung Falls	Paterson, 608 929	25	50–130	Down-stream valley site
C2	Rosewood Gully	Paterson, 641 944	4.5	110–170	Down-stream valley site

CENTRAL SECTOR (continued)

Code designation	Stand name	Map sheet (1: 25 000) and grid reference	Area of stand (ha)	Altitudes of upper and lower margins (m)	Topographic type
C3	Sandy Waterholes Creek	Elderslie, 474 962	16	190–380	Multiple gully-heads
C4	The Valley	Elderslie, 587 976	20	160–330	Single gully-head
C5	Lambs Valley	Elderslie, 553 986	6	130–300	Single gully-head
C6	Billy Brook	Elderslie, 519 985	23	120–310	Multiple gully-heads
C7	Lees Mountain	Paterson, 471 017 (also partly on Elderslie)	11	120–310	Weakly-gullied rocky slopes
C8	Summerhill Rd: N end	Ingar, 581 038	11	110–320	Down-stream valley site
C9	Mirannie Mtn: SE side	Ingar, 452 047	13	170–390	Single gully-head
C10	Mt Tyraman	Ingar, 568 052	4.5	190–360	Down-stream valley site
C11	Oakvale	Ingar, 488 079	14	140–300	Single gully-head
C12	Dark Hole	Ingar, 561 100	17	140–390	Gully-head amphitheatre
C13	Harris Creek	Ingar, 565 115	19	150–340	Gully-head amphitheatre
C14	Mt Dyrring	Ingar S Stand: 358 126 Cent. Stand: 364 132 N Stand: 368 134	S Stand: 5 C Stand: 7.5 N Stand: 3.5	240–400 210–400 230–380	S Stand: multiple gully-head C Stand multiple gully-head N Stand single gully-head
C15	Fenwicks Creek	Ingar, 547 137	16	200–300	Single gully-head
C16	Coulston	Gresford, 619 146	59	110–370	Multiple gully-heads
C17	Upper Myall Creek	Ingar, W Stand: 517 148 E Stand: 528 146	W Stand: 35 E Stand: 14	270–420 250–390	W Stand: gully-heads E Stand: single gully-head
18	Dry Creek	Ingar, 558 152	15	135–240	Down-stream valley site
C19	Breakneck	Carrowbrook, 417 181	22	270–500	Multiple gully-heads
C20	Mt Razorback	Allynbrook, 588 204 (also partly on Carrowbrook sheet)	10	270–420	Weakly-gullied rocky slopes
C21	Masseys Creek	Carrabolla, 568 314	19	200–490	Multiple gully heads
WESTERN SECTOR					
W1	Foy Brook	Dawsons Hill, 228 230	15	250–410	Down-stream valley site
W2	Cedar Creek	Dawsons Hill, 143 244	5	325–430	Gully-head amphitheatre

Appendix 2
Eastern and western sectors: list of species observed in the stands under examination



Notes

- For locality and other information about the individual stands, see Appendix 1.
- Estimates of relative abundance are presented using the following code:

VC	Very common
C	Common
O	Occasional
R	Rare, Very infrequent.

- Taxa are arranged alphabetically at family, generic and specific levels within
- the structural categories of Trees, Shrubs, Herbs, Climbers and Epiphytes–Lithophytes.
- * indicates an introduced species, now naturalised.The stands E5(S) and E5(N) occur very close together. They are identified according to their relative north-south locations. Both E4 and E11 also represent pairs of stands but only a combined species list was obtained for each.
- The final column, Wg, is a general list of those rainforest-related species in the western sector observed to occur singly, in small groups and in small stands. No Herb or Epiphyte–Lithophyte presence lists were obtained for Wg.
- *Arthropteris tenella* and *Microsorium scandens*, usually regarded as epiphytes (e.g. Beadle, 1971), have been placed here in the structural category of Climbers.

RAINFOREST STANDS

EASTERN AND WESTERN SECTORS

		E1	E2	E3	E4	E5 S	E5 N	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	W1	W2	Wg
TREES																						
Alangiaceae	*Alangium villosum*		C	R	O	R	R	R		C	O	O	O		R		R	C				
Anacardiaceae	*Euroschinus falcata*							R		O	R	R			R							R
Araliaceae	*Polyscias elegans*			O	O		O	R	R	O	R	R		R		R	R	R	R	R	O	R
Boraginaceae	*Ehretia acuminata*		R		R		R	O		O	R	R	R			O	O	C	C	R	O	
Capparaceae	*Capparis arborea*	C	C	C	VC	VC	VC	VC	C	C	C	C	C	R	C	VC	C	VC	O	VC	VC	
Celastraceae	*Cassine australis* var. *australis*	R	R	R	C	C	O	O	R	R	R	R	R	R		R	R	R	O	O	O	O
	Maytenus silvestris		R					O				R										O

Appendix 2. (continued)

RAINFOREST STANDS

EASTERN AND WESTERN SECTORS

		E1	E2	E3	E4	E5 S	E5 N	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	W1	W2	Wg
Ebenaceae	*Diospyros australis*	O	C	R	O	O	O	O		O	O	O	O	R	O	O	C	C		C	O	O
	D. pentamera	C		R				O	O	O	O	O	O		O	O			R		O	
Elaeocarpaceae	*Elaeocarpus obovatus*	R	R		O	O		O	O	R	R	O		O	R	R	R	O	R	O	O	C
	Sloanea australis								R	R								C				
Euphorbiaceae	*Actephila lindleyi*		O					O		VC	C	C	O		C	O						
	Alchornea ilicifolia	O		O		O		O	O	O	O	O	O	O	O	O	C	O			C	O
	Baloghia inophylla	O	VC	O	C	C	C	VC		VC		C	O	O	O	O	R	C	C	C	C	R
	Claoxylon australe	O	C	O	O	O	R	C	C	O	C	C	O	O	C	C	O	O	C	C	VC	R
	Cleistanthus cunninghamii	O	O	R	O	O	R	C	O	O	O	VC	VC	C	VC	O	O					
	Croton insularis							O	O			O	R		R		O	R				
	C. verreauxii	O	O	O	C	VC	R	C		O	VC	O	O	O	O	O	C	VC	O	O		O
	Drypetes australasica	C	C	VC	C		O	VC		C	R	O	O	O	O	C	O	C			O	
	Glochidion ferdinandi					C			O	R	O	R										O
	Mallotus philippensis	C	VC	VC	C		C	O		C		C.	VC	VC	C	VC	VC	VC	O	VC		O
	Omalanthus populifolius	R				C			C	R	C							R		R	VC	O
									VC		VC											
Eupomatiaceae	*Eupomatia laurina*				R			R		R												
Flacourtiaceae	*Scolopia braunii*	R		R	O	O	R	O	R	R		R				R		R	O	R	O	O
Gyrostemonaceae	*Codonocarpus attenuatus*											O										
Icacinaceae	*Citronella moorei*				C		R	R		R	R		R					O	R			
	Pennantia cunninghamii		R					R		O	R								O			

Appendix 2. (continued)

Lauraceae	*Cinnamomum oliveri*		R					R													
	Cryptocarya microneura				R			O	R	R							R				
	C. obovata							R			R	R						R	R		
	Litsea reticulata									R					R						
	Neolitsea dealbata		O					O										C	C		R
Malvaceae	*Hibiscus heterophyllus*	O	O	R	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	C	O
Meliaceae	*Dysoxylum fraserianum*		VC	C	C		O	O	O	C	O	O	O	O	O	R	O	O	C	O	O	
	D. rufum											O										
	Melia azedarach	O		O	O			O		O		O	O		O	O	C	C	O	R	R	O
	Synoum glandulosum								O		R											
	Toona australis		R	R			R	O	R	O	R	R	R			R		C	O	O	O	O
Mimosaceae	*Pararchidendron pruinosum*		O		O	O		R	R	O		R	R	O	R	R		R	O	O	O	
Monimiaceae	*Daphnandra micrantha*		C		O	O	R	C	R	O	O	O	R	R		R	C	O	O	C	R	
	Wilkiea huegeliana		O	R	O	O	R	O		O		R	R	R				R	O			
Moraceae	*Ficus coronata*	C	O		R			C		O	C	O	O		R		O	C	C	O		O
	F. fraseri				O		R															
	F. macrophylla	O		O				R	O	C	O	O	O	R	O	O		R				
	F. obliqua							R		R												
	F. rubiginosa	R	R	O	O	O	O	O		O		R		R			R			O		O
	F. superba var. *henneana*	O		O	O		O	R	C	O		R	O		R	R				O	R	R
	Streblus brunonianus	C	VC	C	VC	VC	VC	VC	R VC	C	R VC	C	VC	VC	VC	C	VC	C	VC	VC	VC	C
Myoporaceae	*Myoporum acuminatum*											R										
Myrsinaceae	*Rapanea howittiana*																R					
	R. variabilis		R		O	O	R	R		R		R	R	R					R			C

Appendix 2. (continued)

Myrtaceae	*Acmena smithii*							O		R								R	O			
	Austromyrtus acmenoides	R	R			O		O					R		R			R				
	Backhousia myrtifolia		O			VC				R		R	O	R		R	O			R	R	O
	B. sciadophora	C		VC				C	O	O	C	C	C	VC	C	VC	VC	VC				
	Lophostemon confertus		O																			
	Melaleuca quinquenervia											R										
	M. styphelioides		O	R			R	O		R	R	O	O			R				R	R	
	Rhodamnia rubescens		O			O		O	O	R		R	R				O	R	O	R	R	
	Syzygium australe		R					O		R	R	R	R	R			R O	O	O	O	R	
Oleaceae	*Notelaea longifolia*		O	O	O	O	O	R	O	R	R	O	O	O	O	O	C	O	R	O	O	C
	N. microcarpa var. *microcarpa*		O				O	O														C
	N. venosa	C	R	C	VC	C	VC	C		C	O	O	R	C		C	O			VC	C	O
	Olea paniculata								C													
Pittosporaceae	*Hymenosporum flavum*		R	R			O	O		R	R	R	R		R	R		O	O	O	R	C
	Pittosporum undulatum	O						O		O	R		R				O	R		C	C	C
Proteaceae	*Stenocarpus salignus*			R				R		O		R						O			R	
Rhamnaceae	*Alphitonia excelsa*	R	R	R	R	R	R	O	O	R	R	O	R	R		R	O		R	R	O	R
	Emmenosperma alphitonioides									R					R							R
Rubiaceae	*Canthium coprosmoides*							R							R			R				
	C. odoratum																					O
Rutaceae	*Acronychia oblongifolia*							R										R				
	Geijera salicifolia var. *latifolia*	O		O	C		R	O	C	O	O	O	R	O	O	O	O		R	O	O	O O
	G. parviflora		O	R	R	O	O	R	R	R		R	R	R		R	R	O	R	R	O	R
	Melicope micrococca	R		O	R			R	O	O			O	R	O	R			R	C	C	
	Sarcomelicope simplicifolia																					

Appendix 2. (continued)

Sapindaceae	*Alectryon subcinereus*	O	R	R	C	O	O	R	O	R		R	R	O	R	C	O	O	O	C	C	C
	A. tomentosus	O		C						R	R	O	R	O	R	O						
	Diploglottis australis	R	C	R	C		R	O	O	O	R	O	O	O	R	R	R	O	C	R	O	R
	Elattostachys nervosa	O	O	R	O	O	C	VC		C	O	C	C	C	C	C	R	VC	C			
	Guioa semiglauca		R		O		O	R	R	R		R	R					O	O	R	R	R
	Mischocarpus australis							O	O	O	R	O	R	R	R	O			O			
	Rhysotoechia bifoliolata		R	C	C	C	VC	O	R	O	R	R	R	R	R	O	R					
											R											
									C													
Sapotaceae	*Planchonella australis*	R	O	O	O	O	O	O		O	O	O	O	R	O	O	R	O	VC			
Sterculiaceae	*Brachychiton acerifolius*	O		R					O		R	R			O		R			R	R	
	B. discolor	O		O			R	O		O	O	O	O	C	O	C	R	O		C	O	
	B. populneus		R		R		R		O							R				O		C
	Commersonia fraseri				R			R		O								R			R	
Ulmaceae	*Celtis paniculata*	O		C					C	C		O		C				R				
Urticaceae	*Dendrocnide excelsa*	C	C	O				VC	C	C	O	C	C	C	C	VC	C	C	C	C	V	O
	D. photinophylla	C		C				O	C	R	R	O	C	C	O	C	O	R			C	
Verbenaceae	*Clerodendrum tomentosum*	R		O	O	O	O	O	O	O	O	Q	R	R	R	O	O	R	R	O	C	O
Violaceae	*Hymenanthera dentata*																			O	O	O
SHRUBS																						
Amaranthaceae	*Deeringia amaranthoides*			O				O		R		R				O	R	O				R
	Nyssanthes diffusa									R	R	O				O	O	O				
Caesalpiniaceae *	*Senna floribunda*			R						R			R	O								
Caprifoliaceae	*Sambucus australasica*	R			O		O	R		R	R		R		R	R		R		O	O	
Euphorbiaceae	*Breynia oblongifolia*	R	O		O	O	O	R		R	R		R	O	R	R	O	O	R	O	O	C
Malvaceae	*Abutilon oxycarpum*	O		C				R	O	R	R	O	O	C	O	O	O	O				

Appendix 2. (continued)

Pittosporaceae	*Citriobatus pauciflorus*	VC	VC		VC	C	C	VC	VC	VC	VC	VC	VC	VC	VC	VC	VC	VC	C	VC	C	O
	Pittosporum revolutum	R	O		O	O	C	O	O	R			O	R	O	R	O			O	R	O
Solanaceae	*Solanum aviculare*																	O		O		O
	* *S. mauritianum*											R										
	* *S. pseudocapsicum*																	O				
	S. stelligerum	R	O	O	O	R	R	O		R	R	C	O	O	O	O	O	O	O	O	O	O
Verbenaceae	* *Lantana camara*	VC	O	VC	C	C	O	VC	VC	C	C	O	C	C	C	C	C	C				
	Spartothamnella juncea										R	R			R	O	R					C
Winteraceae	*Tasmannia insipida*																		R			
HERBS																						
Acanthaceae	*Pseuderanthemum variabile*				O	R	O					R	R	O								—
Adiantaceae	*Adiantum aethiopicum*	O	O		O	O	R	C	O	R	O	O	O	O	R	C	O	O	O	C	O	—
	A. formosum	O	C		C	O		C	O	O	C	C	C	C	O	VC	VC	O	VC	C	O	—
	A. hispidulum	R	R		O	R	R	O	R	R	O.	O	O	O	O	O	O	R	C	R		—
	A. silvaticum							R	O	R	R		R					R				—
	Pellaea falcata var. *falcata*	R	C	C	O	C		C	C	O	C	O	R	O	O	C	O	O	C	C	C	—
	P. falcata var. *nana*	O	O	C				O	O	C	O	C	O	O	O	O	C	C	O	O	O	—
	P. paradoxa	O	C	O	O	C	O	O		O	O	R	R	R	R	R		R				—
Araceae	*Alocasia macrorrhiza*							C		R						R		R	O			—
	Gymnostachys anceps		R	O	O	O	O	C	O	O									O			—
Aspidiaceae	*Lastreopsis decomposita*		O					O					O	O	O	O		VC				—
	L. microsora		C			O		R		O	O	O				O	O	O	C			—
Athyriaceae	*Diplazium australe*		O							O						O		O	O			—
Blechnaceae	*Doodia aspera*	R	C		C	C	O	O	O	O	O	O	O	R	R	O	C	O	C	O	R	—

Appendix 2. (continued)

Commelinaceae	*Aneilema acuminatum*		O	R				R		R	R	R		O	R	O	O	O	O			—
	Pollia crispata		R					R		R	R								O			—
Lamiaceae	*Plectranthus parviflorus*							O		R	R			R		R						—
Liliaceae	*Dianella caerulea*							C														—
Pteridaceae	*Pteris tremula*		C					O		O	O	O	O	R	O		O	O	VC	O	O	—
	P. umbrosa		O							R	C	O										—
Thelypteridaceae	*Christella dentata*							R														—
Urticaceae	*Urtica incisa*											R				R			C			—
Violaceae	*Viola hederacea*		O										R	R			R					—
Xanthorrhoeaceae	*Lomandra longifolia*	R	C	O	O		R	C		O	O	O	O	R	O		R	O	O			C
CLIMBERS																						
Apocynaceae	*Parsonsia straminea*	C	C	C	C	O	O	C	C	C	C	O	C	C	C	C	O	C	O	O	O	C
	P. velutina			R	O	O	R	C	R	O	R	R	R	R		R		R	R			
Asclepiadaceae	*Gymnema pleiadenium*			O			C	O	R	R	R				O							
	Marsdenia flavescens	R	R					C			O	R	O	O	O	C	R	O	O			
	M. rostrata		O					O					O		O	C	R		O			O
	M. lloydii	O	C		C		O	R	C	O	O	O		R	O							
Asteraceae *	*Delairea odorata*											R			R	R	C	C				
Bignoniaceae	*Pandorea pandorana*	O	C	R	O	O	R	O	O	O	R	O	O	R	R	C	VC	VC	C	O	O	C
Celastraceae	*Celastrus australis*						O	O		R								R				O
	C. subspicata		R							O		R	R			O	O					
Cunoniaceae	*Aphanopetalum resinosum*		O	O	C	C	C	O	C	O					R	O	O	R	O			C
Davalliaceae	*Arthropteris tenella*		VC		O	O	O	C	R	C	O	O	O	R	O			O	C	R		
Dioscoreaceae	*Dioscorea transversa*	R	O	R	O	O	O	O	R	R	O	O	O	O	O	O	O	O	O	O	O	
Fabaceae	*Austrosteenisia blackii*	VC	VC	C	O	O	VC	VC	C	C	VC	VC	VC	VC	VC	VC	C	C	C			

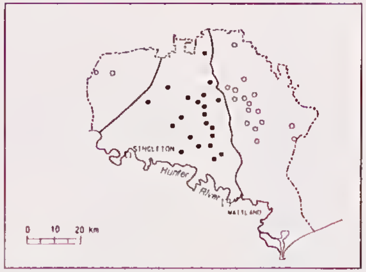
Appendix 2. (continued)

Menispermaceae	*Legnephora moorei*	R	VC	C	O	O	O	C	C	C	C	C	C	C	VC	O	C	C	O			
	Sarcopetalum harveyanum							R		R	R											
	Stephania japonica		R			R		R		R			O			R	O	O	O			
Moraceae	*Maclura cochinchinensis*		O	O	O	O	O	O	O	O	R	O	R	O	R	R	O	O	O	O	O	O
	Malaisia scandens	O	C	O	O	C	C	VC	C	C	O	O	O	O				R	R	O	C	
Myrsinaceae	*Embelia australiana*	C			O			C	O	O		R	O	O	O		R	R	O			
Oleaceae	*Jasminum volubile*	O		VC	VC	VC	VC	O	VC	C	O	C	R	O	O	C						O
Passifloraceae *	*Passiflora edulis*																	R				
	P. herbertiana											O						R			R	
*	*P. subpeltata*						R	R		R				O	R	R		R				
Piperaceae	*Piper novae-hollandiae*							O		O	R	R							R			
Polypodiaceae	*Microsorium scandens*							O		C												
Ranunculaceae	*Clematis glycinoides*							O		R		R						R				
Rosaceae	*Rubus hillii*																	O				
	R. moorei		R					R					R	R				R			O	
Rubiaceae	*Morinda acutifolia*				R			C	O	O	R	O		R								
	M. jasminoides						O	O		C	R	C	O	C	O	O			O		R	
Smilacaceae	*Eustrephus latifolius*		O	R	O	O	O	R	R		R	O	O	O	R	O	R	O	R			C
	Geitonoplesium cymosum			R					R	R												
	Ripogonum album		R					O		R									O			
	Smilax australis		O		O		R	O		R		R	R			R	R	O	O		C	
Vitaceae	*Cayratia clematidea*	O						R		R	O	R	R	O	R	C	R	O	O			
	C. eurynema									O												
	Cissus antarctica	VC	C	C	C	C	C	VC	C	C		VC	VC	VC	C	VC	VC	VC	VC	C	C	C
	C. hypoglauca		R		R			R			VC							R		R		O
	Tetrastigma nitens	O	C	C	C	C	C	C	O	C	R O	O	C	C	O	C	R C	C	O	C	VC	

Appendix 2. (continued)

EPIPHYTES and LITHOPHYTES																						
Aspleniaceae	*Asplenium attenuatum*							O		R	O	O	O		O	R	R	R				—
	A. australasicum	R	O		R	R		C		O		O	R		R			R	C			—
	A. polyodon							R			O											—
Davalliaceae	*Davallia pyxidata*									R												—
Orchidaceae	*Cymbidium suave*									R												—
	Dendrobium gracilicaule	O		R				C	R	O	O	O	R			R		R				—
	D. linguiforme	R		R			O	R	R	R												—
	D. schoeninum											O					O	R				—
	D. speciosum	R	R	R	O	O	C	C	O	C	R	O	O		O	O		O	R	R	R	—
	D. teretifolium			R				R			O	R	R	R	R	R						—
	Liparis sp.									R	R											—
	Plectorrhiza tridentata																					—
	Rhinerrhiza divitiflora									R	R	R										—
	Sacrochilus falcatus			R				O		O	O	O	O		O	R	R	O	R			—
Piperaceae	*Peperomia leptostachya*	R					O	C	O	R	O	C	R	O	R	R	O	R				—
	P. tetraphylla							C	O	O												—
Polypodiaceae	*Dictymia brownii*						O	C		R	O	R			R				R			—
	Platycerium bifurcatum	R	R			R	O	O		O		R			O		R	O	O			—
	P. superbum	R						C		O		O	O	R	O				R			—
	Pyrrosia confluens	O	O	O	C	C	C	VC	O	O	O C	C	O	R	C	C	O	O	O	O	O	—

APPENDIX 3
Central sector: list of species observed in the stands under examination



Notes

- For locality and other information about the individual stands, see Appendix 1.
- Estimates of relative abundance are presented using the following code:

VC	Very common
C	Common
O	Occasional
R	Rare, Very infrequent.

- Taxa are arranged alphabetically at family, generic and specific levels within the structural categories of Trees, Shrubs, Herbs, Climbers and Epiphytes–Lithophytes.
- * Indicates an introduced species, now naturalised.
- The three stands C14(S), C14(C) and C14(N) occur close together. They are identified according to their relative south-central-north locations. Here, only two species lists are presented: under C14(S), a combined list for C14(S) and C14(C) (separate lists not having been made when the field-work was done), and under C14(N) a list for that stand alone.
- The stands C17(W) and C17(E) occur close together. They are identified according to their relative west-east locations.
- The Herb and Epiphyte–Lithophyte presence lists for stand C2 are incomplete.
- *Arthropteris tenella* and *Microsorium scandens*, usually regarded as epiphytes (e.g. Beadle, 1971), have been placed here in the structural category of Climbers.

CENTRAL SECTOR

RAINFOREST STANDS

		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C14	C15	C16	C17	C17	C18	C19	C20	C21
															S	N			W	E				
TREES																								
Alangiaceae	*Alangium villosum*		R		R									R			O	O	R				O	O
Anacardiaceae	*Euroschinus falcata*	R	R	R																				
Araliaceae	*Polyscias elegans*	R	R	O		O	O			R	R		O	R	R		R	O	O	R				
Boraginaceae	*Ehretia acuminata*	R		O		O	C		R		O		R	R	O	O	R	R	O	R	R		O	C
Capparaceae	*Capparis arborea*	VC	C	VC	O	C	VC	C	C	O	C	O	C	O	VC	VC	O	C	C	C	C	C	C	O
Casuarinaceae	*Casuarina cunninghamiana*	R																	R					

CENTRAL SECTOR

RAINFOREST STANDS

		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C14	C15	C16	C17	C17	C18	C19	C20	C21
															S	N			W	E				
Celastraceae	*Cassine australis* var. *australis*	O	O	O	O	O	R	R	R		R	O	O	R	O	O	O	O	C	O	O	C	R	R
	Maytenus silvestris		O																					

Appendix 3. (continued)

Ebenaceae	*Diospyros australis*	O	C	O	O	O		R	R	O	O	O	R		R	O	C	R	O	R	C	O		C
	D. pentamera	O		O	R		O	R		R		R	C				O	C		O		O	O	
						O					C								O					
Elaeocarpaceae	*Elaeocarpus obovatus*	O		C		R	O		R	O	C	O	O	O	O	O	O	O	O	O	R	O	C	C
	Sloanea australis																							R
Euphorbiaceae	*Actephila lindleyi*	R		C	R						R							O						
	Alchornea ilicifolia	C	C	O	C	O	C	O	O	C	O	O	O		C	O	O	O			O	O	R	
	Baloghia inophylla	C	C	C	VC		V		C	R		C	O	O	VC	C	C	C	C	O	R	C	O	R
	Claoxylon australe	O	C	V	C	C	C	R	O		C		O	R	C	O	O	O	O	O	O	O	C	O
	Cleistanthus	C	C	C	C	R	C	O	VC	VC	O	O	V	VC			VC	VC		VC	C		VC	
	cunninghamii	R		C		C	V					R	C					R	O					
	Croton insularis	C	VC	R	O		C	V	O	C	V	C		O	VC	C	C	O		C	C	V	O	C
	C. verreauxii	V	VC	V	VC	O	R	C	C	C	C	C	O	R			O	O				C		
	Drypetes australasica	C	C	C			V	O	R				C						C		R			
	Glochidion ferdinandi		C	V	VC	V	C		VC	VC	C	VC	R	VC	C	V	VC	O		O	C		VC	O
	Mallotus philippensis	V		C		C	C	C			C		C			C						O		R
	Omalanthus populifolius	C		R				C																
				V		V	C	R			C								R					
				C		C	R	V																
						R		C																
Eupomatiaceae	*Eupomatia laurina*				O		R						R	O				R	R	R			R	O
Flacourtiaceae	*Scolopia braunii*	O	O	O		O	O	O	R		O	O	O	O	R	O	C	O	O	O	O	R	R	R
Icacinaceae	*Citronella moorei*			R			R										R		R	R			R	
	Pennantia cunninghamii																						R	O
Lauraceae	*Cryptocarya glaucescens*																							R
	C. microneura	R		O			R												O	R		O		O
	C. obovata				R								R					R						
	Litsea reticulata																						R	
	Neolitsea dealbata														R				R					VC
Malvaceae	*Hibiscus heterophyllus*	O	C	V	O	R	O	O	O	O	O	O	O	O	O	O	O	O	C	O	O	O	O	O
				C																				
Meliaceae	*Dysoxylum fraserianum*	O	O	O	O	O	O		O			O	R	O	O	O	C	R	O	O		O	O	C
	Melia azedarach	O			R			O	R		R	R	R	R			O	O			C		O	O
	Synoum glandulosum	O																						
	Toona australis	R		R	R		O		R	R	O	R	R		O	O	R	R			O	O	R	C
						R		R											O					
Mimosaceae	*Pararchidendron*	O		O		R	R	R	O		O	R	R		R	O		R	R	R	R	R	R	
	pruinosum																							
Monimiaceae	*Daphnandra micrantha*	O	R	O	O		O							R	C	C	R	R	O	R		R	R	VC
	Wilkiea huegeliana	O		O	R		R					R			R	R	R	R			R	O		R
																			O					

Appendix 3. (continued)

Moraceae	*Ficus coronata*	O	C	R	C	O	O		O			R			C	C		R	C	R	O	O		O
	F. macrophylla	O	O		O			O	R	O	R		O	R			O	O					O	
	F. rubiginosa	R	O	R	R	O	R		R	O	O	O	O	C	O	R		R			R	O	O	R
	F. superba var.	R	O		R		R	R		R			R	R				O	R		R	R	R	
	henneana	V	VC	V	VC	O	V		VC	VC	O	VC	V	VC	VC	V		VC	V	VC	VC	V	VC	O
	Streblus brunonianus	C		C			C	V					C			C			C			C		
						R		C			V													
						V					C													
						C																		
Myoporaceae	*Myoporum acuminatum*																					R		
Myrsinaceae	*Rapanea howittiana*		C	R															R					
	R. variabilis	O	O	R		R			R	R	R	R	R				R		R		R			R
Myrtaceae	*Acmena smithii*			R															R					O
	Austromyrtus	R		R			R		R		O		R		R	R	O	O	O	R	R	O	R	R
	acmenoides	R	VC	R	O	O		O	O	O		C	O		O		C				R	C		
	Backhousia myrtifolia																		C				R	
	B. sciadophora	R		O																		R		R
	Melaleuca	O					O		R	O		O	C	O	O	O	O	O		C	C	C	O	R
	quinquenervia			R	O	O	R				O				R		R	R	O	O	R	O		O
	M. styphelioides	O	C	O	O				O				O		O	O		O		R	R	C	O	O
	Rhodamnia rubescens	R									R								O					
	Syzygium australe																							
	Tristaniopsis laurina																		C					
Oleaceae	*Notelaea longifolia*	O	C	C	R	O	O	R	R	O	O	O	O	O	O	O	O	O	O	R	O	O	R	R
	Olea paniculata	C	VC	O	C		C	C	C	O		C	C	C	C	C	C	O			O	O	O	
						C					C								R					
Pittosporaceae	*Hymenosporum flavum*		O	O	R		O			O	R	R			C	O	R	R	O	O	O	O	R	R
	Pittosporum undulatum	R	C	R		R				O		R	R		R	O	R				R	R	R	O
																			R					
Podocarpaceae	*Podocarpus elatus*	R	R							R	R		R					R					R	
Proteaceae	*Stenocarpus salignus*			C								R					R		R					R
Rhamnaceae	*Alphitonia excelsa*	R	O	O		R	R	R				R	R		R	R	C	O	R	R	C	O	R	R
	Emmenosperma	R			O																			
	alphitonioides																							
Rubiaceae	*Canthium coprosmoides*														R		O				R			
Rutaceae	*Acronychia oblongifolia*	R		O															R					
	Geijera salicifolia var.	C	R	C	O	O	C	C	O	O	O	C	C	O	O	R	O	C	O					
	latifolia	O	R	R	R							R		R			R	R				O		R
	Melicope micrococca	C	R	O	C		R	O	R	C		R	R	O	C	O	C	O	O	C	C	R	O	R
	Sarcomelicope					O					O									O	O		R	O
	simplicifolia																		R	R	R	C	O	

Appendix 3. (continued)

Sapindaceae	*Alectryon subcinereus*	O		O		O	O	O	O	O	O	C	O	O	R	R	O	O	O	O	C	O	O	O
	A. tomentosus	O							O	R		O	C	O				R		R	O		R	
	Diploglottis australis	R	O	O	O	O	C	C			O	R			C	O	O	O		R	R	O	O	O
	Elattostachys nervosa	C	C	C	O		O		R			O	O	O			O	C	O	O	R		O	
	Guioa semiglauca	O	R	O	R	R	O	R			R	R	R	R	O		R			R		R	R	R
	Mischocarpus australis	O	R	O		R	O				O		O					O	R	C		C		O
	Rhysotoechia bifoliolata	C		C	O		R		R	O		R	R	O			O	C	O				O	
						R		R			R													
						R					R								C					
											R								R					
Sapotaceae	*Planchonella australis*	C	O	C	C		C	R	O	O	O	R	O		O	O	O	C	C	O	C	O	C	O
Sterculiaceae	*Brachychiton acerifolius*			R		R	O								R			R				O		
	B. discolor	C	O		O	O	R	R	O	O	O	O	O	R	O	O	O	O	O	R	O	R	C	R
	B. populneus	R		O																				
	Commersonia fraseri											O										R		R
Symplocaceae	*Symplocos thwaitesii*																		R	R				
Ulmaceae	*Celtis paniculata*																	R						
Urticaceae	*Dendrocnide excelsa*	O	O	O	C	O	V	C	C	C	O	R	O	O	O	C	O	C	O	C	C	O	C	O
	D. photinophylla	C	O	R			C	C	O	C		O	O	R			O	O						
							R				R													
Verbenaceae	*Clerodendrum tomentosum*	O		O	O	R	R	O	R	R		O	O	R	O	R	R		O	O	O	O	O	R
SHRUBS																								
Amaranthaceae	*Deeringia*						O			R	R				O	R			R			R		
	amaranthoides						R			R	R											R		
	Nyssanthes diffusa																							
Araliaceae	*Astrotricha latifolia*																	R						
Caesalpiniaceae*	*Senna floribunda*	O							R															
Caprifoliaceae	*Sambucus australasica*			R			R	O								R		R	O			O	O	R
Euphorbiaceae	*Breynia oblongifolia*	O	C	O	O	R	R	O	O	O	R	O	O	R	O	R	R	R	R	R	R	R		R
Malvaceae	*Abutilon oxycarpum*		O			O	R	C	O	C	O	C	C	O	O	O	O	O		O	O	R	O	
Pittosporaceae	*Citriobatus pauciflorus*	V	VC	V	VC	V	V	V	VC	VC	V	C	V	C	VC	V	VC	VC	V	VC	VC	V	VC	VC
	Pittosporum revolutum	C	O	C		C	C	C			C	O	C			C			C		O	C		O
				R							O											O		
Solanaceae	*Solanum aviculare*							R					R				R		R					
	S. stelligerum	O		O	R	R	R	C	R	O	O	O	O	R	O	O	O	O	O	O	O	O	C	O
Verbenaceae *	*Lantana camara*	V	VC	V	VC	C	O	V	C	VC	O	C	C	VC			O	C			VC			
	Spartothamnella juncea	C		C				C		R														

Appendix 3. (continued)

Zamiaceae	*Macrozamia* sp.										O													
HERBS																								
Acanthaceae	*Pseuderanthemum variabile*		—		R		R		O	R	R	O			O	R		R	O	O		R	O	
Adiantaceae	*Adiantum aethiopicum*	C	—	O	O	C	O	O	C	C	C	C	C	C	O	O	R	O	O		C	O	R	O
	A. formosum	O	C	C	C	O	V		O	O	C	R	O		VC	C	C	C		C	O	C	O	C
	A. hispidulum	O	C	R	O		C	R	O	R	O	O	C	R	C	C		R	V	O	R	C	R	O
	A. silvaticum		—			C	R	O				O		R					C	O		R		
	Pellaea falcata var.	C	C	C	VC	R			R	R		O	R	C	C	C	C	R	O	O	C	O	R	O
	falcata	O	—	O	O	O	O		O	R	O	O	O	R	O	O	R	C		R	O	O	R	O
	P. falcata var. *nana*	C	O	C	O		R	O	R	C		R	O	R			O	R			O	R	O	R
	P. paradoxa					C	O				O								O					
						O																		
								O			O								R					
																			R					
Araceae	*Alocasia macrorrhiza*		—																R					R
	Gymnostachys anceps	O	—				O								R	R						R		R
Aspidiaceae	*Lastreopsis decomposita*		—												R			O	V	C				O
	L. microsora		—				O			R	O				C	O		R	C			O		O
Athyriaceae	*Diplazium australe*		—				O								R							R		R
Blechnaceae	*Doodia aspera*	O	—	C	C	O	C		O	O	C	O	C	O	C	O	C	O	O	C	VC	V	R	C
																						C		
Commelinaceae	*Aneilema acuminatum*		—			O	R		C	R		O	O		R	R	O		O	O	C	R		
	Pollia crispata		—																					
																			R					
Lamiaceae	*Plectranthus parviflorus*		—		R			R	R	R	R	R	O					R	O	O	O		R	
Liliaceae	*Dianella caerulea*		—						R															
	Tripladenia cunninghamii		R																					
Pteridaceae	*Pteris tremula*	R	—	R	O	R		R	R			O	O	O	R		O	O	O	O	O		O	O
	P. umbrosa		—		O															R			O	VC
																			R					
Thelypteridaceae	*Christella dentata*		—																R					
Urticaceae	*Urtica incisa*		—				O			R														
Violaceae	*Viola hederacea*		—			R	O	R	O	O	R	R	R				O			O	C	O	O	
Xanthorrhoeaceae	*Lomandra longifolia*	O	C	C	O	R	O		R		O	O	R	R	C	O	O	O	O	O	R	O	R	O

Appendix 3. (continued)

CLIMBERS

Apocynaceae	*Parsonsia straminea*	C	C	O	C	V	V	C	C	C	C	C	C	C	C	C	VC	C	V	VC	O	C	O	C
	P. velutina	R		R	R	C	C				C				O	O		R	C					O
							O												R					
Asclepiadaceae	*Gymnema pleiadenium*										O				R			R						O
	Marsdenia flavescens		C		O	O	O		O	O			C		VC	C		O	O	VC	O	C		C
	M. rostrata						O				C				O	O						O	C	C
	M. lloydii				O			O	R	C		O	C	O				O			R			
											O								O					
Asteraceae *	*Delairea odorata*																						O	
Bignoniaceae	*Pandorea pandorana*	O	C	O	O	O	V	O	O	VC	O	C	O	O	VC	V	O	C	O	C	O	V	O	VC
							C									C						C		
Celastraceae	*Celastrus australis*											R												
	C. subspicata				R	R			O						O	O	R					C		O
Cunoniaceae	*Aphanopetalum*		R	R		O	O		R	O	O	O	O	R	O	C		R	O	R	O	V	R	O
	resinosum																					C		
Davalliaceae	*Arthropteris tenella*	R	C	O	C	C	O		O	R	O	R	O	C	O	O	O	C	O	O	R	O	O	O
Dioscoreaceae	*Dioscorea transversa*					O	O		O	R	O	O		O	C	C		O	O	O	R	C	O	C
Fabaceae	*Austrosteenisia blackii*	C	VC			O	C	C	VC		R			O				VC			VC		VC	
Menispermaceae	*Legnephora moorei*	O	R	O	O	O	C	O	O	O	O	O	O	C	O	C	C	C	R		O	C	C	C
	Sarcopetalum			O			R			R								R				R		
	harveyanum							R				R	R						O			R		O
	Stephania japonica					O																		
Moraceae	*Maclura cochinchinensis*	O	O	O	C	C	O	C	O	O	O	R	C	O	O	O	O	O	O	O	C	O	O	O
	Malaisia scandens	O	O	O	C	R	V	O	O			O	O	O	O		C	C		O	R		C	R
							C				O								C					
Myrsinaceae	*Embelia australiana*	O		C	C	O		R		R	R	O	R		O	O	O	O	C	O	R	C		O
Oleaceae	*Jasminum volubile*	C	C	O	O	C	O	O	O	O	O	O	C	R			R	O			C		R	
Passifloraceae	*Passiflora herbertiana*							R		R		R												
*	*P. subpeltata*						R						R									R	R	
Ranunculaceae	*Clematis glycinoides*												R	R										R
Rosaceae	*Rubus moorei*										R									R				R

Appendix 3. (continued)

Rubiaceae	*Morinda acutifolia*	C	O																					
	M. jasminoides			R	O	O		O	R								C	C	C				C	
Smilacaceae	*Eustrephus latifolius*		C		O	R	R	O		R	R	O	R	O	R	O	O	R	R	R	R	O	R	R
	Geitonoplesium										O													
	cymosum			O	R	O	R											O		O			R	
	Ripogonum album														O	O	R	R	O		R	O		R
	Smilax australis					R					O													
Vitaceae	*Cayratia clematidea*			R	O	O	O	C	O	C	R	O	O	O	O	O	O	O	R	O	O		O	O
	Cissus antarctica	C	VC	C	C		V	O	VC	C	C	C	C	C	VC	V	C	C	V	VC	VC	V	VC	VC
	C. hypoglauca			R	R	V	C							R	O	C		R	C			C	R	O
	Tetrastigma nitens	C	VC	V	C	C			C	O	C	O	C	VC	C	O	C	C	O	C	C	O	C	C
				C			C	C								O						C		
						O													C					
EPIPHYTES and LITHOPHYTES																								
Aspleniaceae	*Asplenium attenuatum*		—		R	R			R				R					O	R					
	A. australasicum		—												R	R		R	O			R	R	R
	A. polyodon		—				R																	
Orchidaceae	*Dendrobium gracilicaule*		—	R	O	R					O		R		R	R		R	O			R		
	D. linguiforme	R	—		R					R			R	R	R									
	D. schoeninum		—		O														R					
	D. speciosum	O	—	R	O	O	O		R				O					O					R	O
	Plectorrhiza tridentata		—				R				R								R			R		
	Sacrochilus falcatus	R	—				R			R			O				O	O		R	O	C	R	
	S. hillii		—								O								O	R				
	S. olivaceus		—				R																	
Piperaceae	*Peperomia leptostachya*		—			O			O	O	O		O			R		R				O		
	P. tetraphylla		—																					
						R																		
Polypodiaceae	*Dictymia brownii*	R	—							R					O	R			R					
	Platycerium bifurcatum	R	O		R	O	O		R	R		R	R		R	R	R	R	O	R	R	O	R	
	P. superbum		—				O						R				R	O					R	R
	Pyrrosia confluens	O	—	V	C		C	R	O	O	O	O	C		O	O	R	O		O	O	C	O	C
	P. rupestris		—	C		C													C			O		O
																			R					

Observations on the effects of mowing on native species in remnant bushland, western Sydney

T.A. James

James, T.A. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1994. Observations on the effects of mowing on native species in remnant bushland, western Sydney Cunninghamia *3(3): 515–519*. Native plant species were recorded in 1989 from Gum Tree Reserve, a small area of remnant Turpentine–Ironbark Forest in western Sydney, after many years of frequent mowing. A further list was compiled in 1993, one year after a change to a less frequent mowing regime. Within this time the number of native species recorded increased threefold. Future management options are discussed with regard to encouraging further regeneration of native species and re-establishing the soil seed bank.

Introduction

Small bushland remnants in western Sydney are subject to many pressures as a result of their size and proximity to suburban housing. With an increasing need to preserve biodiversity in the suburban context (Benson & McDougall 1991), it is now recognised that such areas are important conservation sites for their scientific, ecological, educational and heritage values and should be managed to retain their native species. The 'tidying' of areas by mowing is a widespread management practice which may reduce overall native species richness (Kirkpatrick 1986). A reduction or elimination of mowing could, therefore, allow native species to re-establish and help prevent further decline in species richness. An opportunity arose to test this hypothesis at Gum Tree Reserve in a residential area of Guildford, western Sydney. The site had been mowed frequently, approximately six times a year, probably for up to 20 years prior to July 1992 (Water Board pers. comm.). A checklist of the area was compiled by the author during this period, in August 1989. Since July 1992 Holroyd City Council have opted for a regime of less frequent mowing. The site was mowed in July 1992 and subsequently in December 1992 with no further mowing to date (Holroyd City Council pers. comm.). The opportunity was taken to record the native species present at the site in June/July 1993 to assess any change in species richness resulting from the altered mowing regime.

Study site

Gum Tree Reserve is a 0.75 ha block of land in Harris Street, a residential area of Guildford, western Sydney, about 4.5 km south-west of Parramatta (33° 51' 12" S, 150° 58' 28" E), situated on the Cumberland Plain. The underlying geology is the Liverpool subgroup of Wianamatta Shale. The average annual rainfall is approximately 940 mm (Bureau of Meterology 1979). The Reserve is a site of regrowth native woodland which, except for an adjacent Water Board pipeline corridor, is isolated by urban development. The nearest remnant bushland is at Duck Creek, Auburn, 3 km due east of the site, and at Prospect Creek, 2 km south-west of the site. The threat of development in the late 1980s motivated local residents to appeal to Holroyd City Council for conservation of the area as a local reserve.

The vegetation of the area is consistent with a drier form of Turpentine–Ironbark Forest once growing in districts west of Auburn (Benson & Howell 1990). The site is dominated by *Eucalyptus fibrosa* and *E. moluccana*, with occasional trees of *E. paniculata*, and one remaining tree each of *Syncarpia glomulifera* and *E. longifolia*. The understorey is poorly developed due to a history of clearing and regular mowing at the site. The few surviving small trees and shrubs include *Acacia parramattensis*, *Pittosporum undulatum*, *Bursaria spinosa*, *Rapanea variabilis* and *Maytenus silvestris*, most of which are located on the northern boundary of the reserve next to adjoining residences. Several exotic species (garden escapes) including *Tecoma capensis*, *Bryophyllum pinnatum* and *Bougainvillea* species have become established along this boundary. Holroyd City Council staff have recently planted several trees along the southern boundary (adjacent to pipeline corridor) including *Melaleuca linariifolia*, *M. styphelioides*, *Acacia floribunda* and *Eucalyptus* species. At least the first three species are native to the local area. Some trees of *Eucalyptus paniculata* may have been planted by the Water Board (D. Thomas pers. comm.).

Methods

Native plant species present in the reserve were recorded in August 1989, and subsequently during June–July 1993 by systematically walking the site. Observations on growth form, flowering/fruiting and means of regeneration were also made in June–July 1993.

Results

In 1989 when the site was regularly mowed, only 14 native species were recorded (Table 1). In contrast, in 1993 after a year of reduced frequency of mowing, a three-fold increase in the number of native species (14 to 45) was recorded. The regeneration of tree and shrub species was minimal, with only early stages of regrowth evident. However, there was significant regeneration of herbs, subshrubs and climbers, which accounted for 96% of the newly recorded species in 1993. Of the 45 species listed for Gum Tree Reserve, 68% are new records or have been recently recorded for the Holroyd Council area, and 13 species are considered vulnerable in western Sydney (Benson & McDougall 1991).

The dominant native grasses were perennial species including *Danthonia linkii*, *Digitaria parviflora*, *Paspalidium distans* and *Eragrostis leptostachya*, all of which were flowering or seeding at the time of the second survey. These species were well represented, particularly in areas away from the reserve boundaries, despite competition from exotic species including *Eragrostis curvula*, *Chloris gayana*, *Paspalum dilatatum*, *Sida rhombifolia* and *Plantago lanceolata*. Dominant species in the ground layer, other than grasses, were low-growing native shrubs, herbs and climbers with persistent rootstock and/or a stoloniferous habit including *Brunoniella australis*, *Einadia hastata*, *E. polygonoides*, *Dichondra repens* and *Glycine microphylla*.

As expected, there was minimal regeneration of tree and shrub species due to their longer life cycles. Limited suckering around the base of the *Eucalyptus* species was observed. The most extensive and vigorous regrowth of the larger shrub species was of *Maytenus silvestris* and *Rapanea variabilis*. Regeneration was primarily from existing rootstock, often in close proximity to the mature trees. Regeneration was also evident in *Polyscias sambucifolia*, *Pittosporum revolutum* and *Clerodendrum tomentosum*. The only seedlings observed were of *Acacia parramattensis*. Soil surface conditions appeared to

Table 1. Native plant species recorded from Gum Tree Reserve, Guildford in August 1989 following regular mowing (on average every 2 months), and in June/July 1993 after a change to a less frequent mowing regime. Regular mowing ceased in July 1992 with a 6 month break before a final mowing in December 1992.

Family	Species	Growth form	Aug 1989	Jun/Jul 1993	Regeneration
Monocotyledons					
ANTHERICACEAE	*Arthropodium milleflorum*	Gr		* Fr	R
CYPERACEAE	*Cyperus gracilis*	Gr		* Fl	R
JUNCACEAE	*Juncus usitatus*	Gr		* Fl	R
LUZURIAGACEAE	*Eustrephus latifolius* **V**	Cl		*	R
POACEAE	*Aristida vagans*	Gr		* Fl/Fr	R
	Chloris truncata **V**	Gr		* Fr	R
	Danthonia linkii var. *linkii* **V**	Gr		* Fl	R
	D. racemosa **V**	Gr		* Fl	R
	Digitaria parviflora	Gr		* Fl	R
	Elymus scaber **V**	Gr		*	R
	Eragrostis leptostachya	Gr		* Fl	R
	E. sororia	Gr		* Fl	R
	Microlaena stipoides	Gr		* Fl	R
	Panicum simile	Gr		* Fl	R
	Paspalidium distans	Gr		* Fl/Fr	R
	Sporobolus creber **V**	Gr		* Fl	R
	Stipa rudis subsp. *nervosa* **V**	Gr		* Fr	R
Dicotyledons					
ACANTHACEAE	*Brunoniella australis*	Gr		*	R
ARALIACEAE	*Polyscias sambucifolia* **V**	Sh		*	R
ASCLEPIADACEAE	*Tylophora barbata* **V**	Cl		*	R
ASTERACEAE	*Vernonia cinerea* var. *cinerea*	Gr		* Fl	R, ?S
BIGNONIACEAE	*Pandorea pandorana* **V**	Cl	*	*	R
CAMPANULACEAE	*Wahlenbergia gracilis*	Gr		*	R, ?S
CELASTRACEAE	*Maytenus silvestris*	Sh	*	*	R
CHENOPODIACEAE	*Einadia hastata*	Gr	*	* Fl/Fr	R, S
	E. nutans	Gr		*	R
	E. polygonoides **V**	Gr		* Fl/Fr	R, S
CONVOLVULACEAE	*Dichondra repens*	Gr		*	R
EUPHORBIACEAE	*Breynia oblongifolia*	Sh	* Fl/Fr	* Fl/Fr	R, ?S
FABACEAE (Faboideae)	*Desmodium varians*	Gr		*	R
	Glycine microphylla **V**	Cl		*	R
FABACEAE (Mimosoideae)	*Acacia parramattensis*	Tr	*	*	S
LORANTHACEAE	*Amyema ?congener*	Aerial parasite	*	*	
MYRSINACEAE	*Rapanea variabilis*	Sh	* Fl	*	R
MYRTACEAE	*Eucalyptus fibrosa*	Tr	* buds, Fr	* buds, Fr	R (minimal suckering)
	E. longifolia **V**	Tr	*	* Fl,Fr	R (minimal suckering)
	E. moluccana	Tr	* buds, Fr	* buds, Fr	R (minimal suckering)
	E. paniculata	Tr	* buds, Fr	* buds, Fr	R (minimal suckering)
	Syncarpia glomulifera	Tr	*	*	R
PITTOSPORACEAE	*Bursaria spinosa*	Sh	* Fr	* Fr	R, ?S
	Pittosporum revolutum	Sh	*	R	
	P. undulatum	Sh	*	*	None
RANUNCULACEAE	*Clematis glycinoides*	Cl	*	R	
SCROPHULARIACEAE	*Veronica plebeia*	Gr	*	R	
VERBENACEAE	*Clerodendrum tomentosum* **V**	Sh	*	R	

Key

V = vulnerable in western Sydney. Growth form: Tr= Tree, Sh= Shrub, Cl= Climber, Gr= Ground (herbs or subshrubs with renewal buds at or near surface). Regeneration = means of regeneration recorded: R = rootstock, S = seed, * = species present: Fl = flowers present; Fr = fruit present. Nomenclature follows Harden (1990–93).

be suboptimal for germination and seedling growth, with large areas exposed with dry, hard soil and minimal accumulations of organic matter.

Discussion

The 'new' species recorded in the second survey were predominantly herbs, subshrubs and climbers capable of vegetative regeneration. This is consistent with previous studies that indicate mowing will promote a community dominated by plants with renewal buds near or below the ground surface and with short life cycles (Buchanan, 1989). These resprouters may have been present at the time of the initial survey but were not readily identifiable due to frequent defoliation by mowing. It is unlikely that recolonisation from the adjacent Water Board corridor or other remnant vegetation in the district could satisfactorily explain the documented increase in native species richness. Although c. 100 native species have been recorded from upper sections of the pipeline corridor (D. Thomas 1993), only 37% were also recorded at the study site.

The lack of seedlings could indicate that the soil seed bank has been severely depleted due to long-term mowing of the site, although some seed may be dormant awaiting favourable conditions for germination and establishment. The long-term viability of seed for different species is poorly documented, but estimates for *Acacia* species may be as high as 50 to 100 years (New 1984). The high percentage of grasses and herbs flowering or fruiting at the time of the second survey indicates a significant potential input to the soil seed bank within 12 months of the change of mowing regime. Further investigations including documentation of the size, composition and viability of the soil seed bank are needed.

To allow significant tree and shrub regeneration there should be no mowing for several years. In the longer term, a reduced mowing regime may need to be implemented to address concerns regarding both the appearance of the site and any potential fire hazard. Mowing could occur once every two or three years or when there is a high fire risk, at least along the northern boundary adjacent to local housing. A mosaic mowing regime may be feasible whereby selected areas are mowed at different frequencies and/or heights. This approach could reduce fire hazards where needed, provide some public access, protect regenerating trees and shrubs, and promote the growth of herbs and subshrubs. Mowing may also be useful in the control of some weedy species, but the timing, frequency and height of cutting must be closely related to the phenology of individual species. The use of control burning could also be considered, although there are limitations with the small size of the area and the close proximity of housing.

Conclusions

The present species composition of the woodland in Gum Tree Reserve suggests that the site was once part of a western outlier of Turpentine–Ironbark Forest. There are no other examples of this vegetation type existing in the local district today and consequently, despite its small size, it is of significant heritage and scientific value. The botanical significance of the site is highlighted by the large proportion of native species not previously recorded in the Holroyd Council area and 13 species considered vulnerable in western Sydney (Benson & McDougall 1991).

The long history of frequent mowing at the site is likely to have resulted in the loss of some native species. Conditions favour the persistence of species with protected renewal buds, persistent underground rootstock and short life cycles. An increase in species richness (14 to 45 species) was documented within 12 months of the change in mowing regime. This increase is probably chiefly due to regeneration of these persistent species which were not readily identifiable in the initial survey. The possibility of some degree of recolonisation from the adjacent pipeline corridor also exists. Regeneration was primarily by vegetative means. The soil seed bank may be severely depleted or a small store of dormant seeds may exist awaiting favourable conditions. A major limitation of the survey is the absence of a control area that has not been mowed for comparison. The effect of other environmental factors, therefore, cannot be eliminated.

To restore the original vegetation of the site, natural regeneration must be encouraged. This could be achieved by stopping all mowing at the site for an initial period of 1–2 years and then instituting an infrequent or mosaic mowing regime. Maximum protection should be given to regenerating trees and shrubs. Additional management practices including the propagation of vegetative or seed material collected from the site should be considered. Exotic species need to be controlled within the reserve, particularly along the northern boundary where garden escapes have become established.

Despite the limitations of the study, the results indicate that reduced frequency of mowing can have positive effects on native species richness. The apparent persistence of many native species despite long-term mowing is of interest. The implications of these results for the management of urban bushland areas by local councils warrants recognition. It is important that detailed documentation of such remnant bushland is undertaken and appropiate priorities and management practices adopted.

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The effect of time since fire on the cover and composition of cryptogamic soil crusts on a eucalypt shrubland soil

D.J. Eldridge and R.A. Bradstock

D.J. Eldridge[1*] *& R.A. Bradstock*[2] *(*[1]*Department of Conservation & Land Management, PO Box 77, Condobolin, NSW 2877** [2]*NSW National Parks & Wildlife Service, PO Box 1967, Hurstville, NSW 2220) 1994. The effect of time since fire on the cover and composition of cryptogamic soil crusts on a eucalypt shrubland soil.* Cunninghamia *3(3): 521–527.* We investigated the cover and composition of cryptogams at a number of mallee (*Eucalyptus* spp.) sites with different periods of recovery since fire. Total cryptogam cover increased with time since fire, and maximum cover of 52% occurred at sites with 16 years of recovery since fire. Increasing the interval since fire increased the contribution of crustose lichen to total cover and decreased the contribution by algae. The results suggest that fires less than ten years apart are generally likely to maintain cryptogam cover at low (< 20%) levels and lead to a dominance by algae.

Introduction

Eucalypt shrublands occupy an extensive area of Australia, and their ecological and economic significance is well established (Noble & Bradstock 1989). Mallee eucalypts (*Eucalyptus* spp.) are restricted to aeolian soils (Eldridge 1986), which are weakly structured, highly erodable by wind and water, and characterised by low levels of organic matter and available nutrients. In these communities, cryptogamic soil crusts occupy large areas of ground between individual shrubs. These crusts, which comprise mosses, lichens, algae and liverworts, help to stabilise the soil surface against water erosion (Fletcher & Martin 1948, Eldridge & Greene 1994). Their presence is linked to changes in vascular plant survival and nutrient cycling (West 1990).

Fires are a feature of many semi-arid landscapes, and occur regularly in eucalypt shrublands of eastern Australia (Bradstock 1989, Noble 1984). As well as altering the structure and composition of the shrub and herbaceous layers, fires affect the cryptogamic components of the soil surface. Studies on different soil types in other semi-arid grazing systems (e.g. Greene et al. 1990, A.M. Gill pers. comm. 1993), have shown that fire has the capacity to destroy gels and mucilaginous sheaths associated with cryptogams and fungal hyphae in the crusts. This results in a breakdown in the spatial integrity of the crust, increased erosion (Kinnell et al. 1990) and reduced infiltration through a decline in aggregate stability and density of fungal hyphae (Greene et al. 1990).

Although the rate at which cryptogamic surfaces recover after fire has been variously reported in the literature for some soil and rangeland types, there are no data for aeolian soils. Reported rates for complete recovery in other systems vary from 4 years (Greene et al. 1990) to more than 20 years (Callison et al. 1985). In January 1992 we commenced a study to investigate the rate of recovery of cryptogamic soil crusts after fire, on an aeolian soil dominated by mallee species at a range of sites with different intervals since fire.

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Methods

Study area

The study was conducted in eucalypt shrublands at Yathong, Round Hill and Nombinnie Nature Reserves in central-western New South Wales (Figure 1). The landscape is characterised by long undulating sandplains with slopes of < 2% on which are superimposed subdued low rises to 2 m in relief. Soils on the sandplains are predominantly calcareous sands (Uc5.12; Northcote 1979) and those on the rises an assortment of calcareous sands and siliceous sands (Uc1.13; Northcote 1979).

Vegetation was similar on the sandplains and rises, with a shrub overstorey dominated by stunted mallees (particularly *Eucalyptus socialis, E. dumosa, E. leptophylla* and *E. gracilis*) and a perennial shrub understory dominated by *Acacia rigens, A. wilhelmiana, A. triptera, A. havilandii* and *Melaleuca uncinata. Callitris preissii* subsp. *verrucosa* was more common on the low rises, and *Triodia irritans* was locally dominant at all sites. Recently burnt sites possessed a ground layer composed of ephemeral forbs and grasses (e.g. *Haloragis odontocarpa, Goodenia* species, *Stipa* species.)

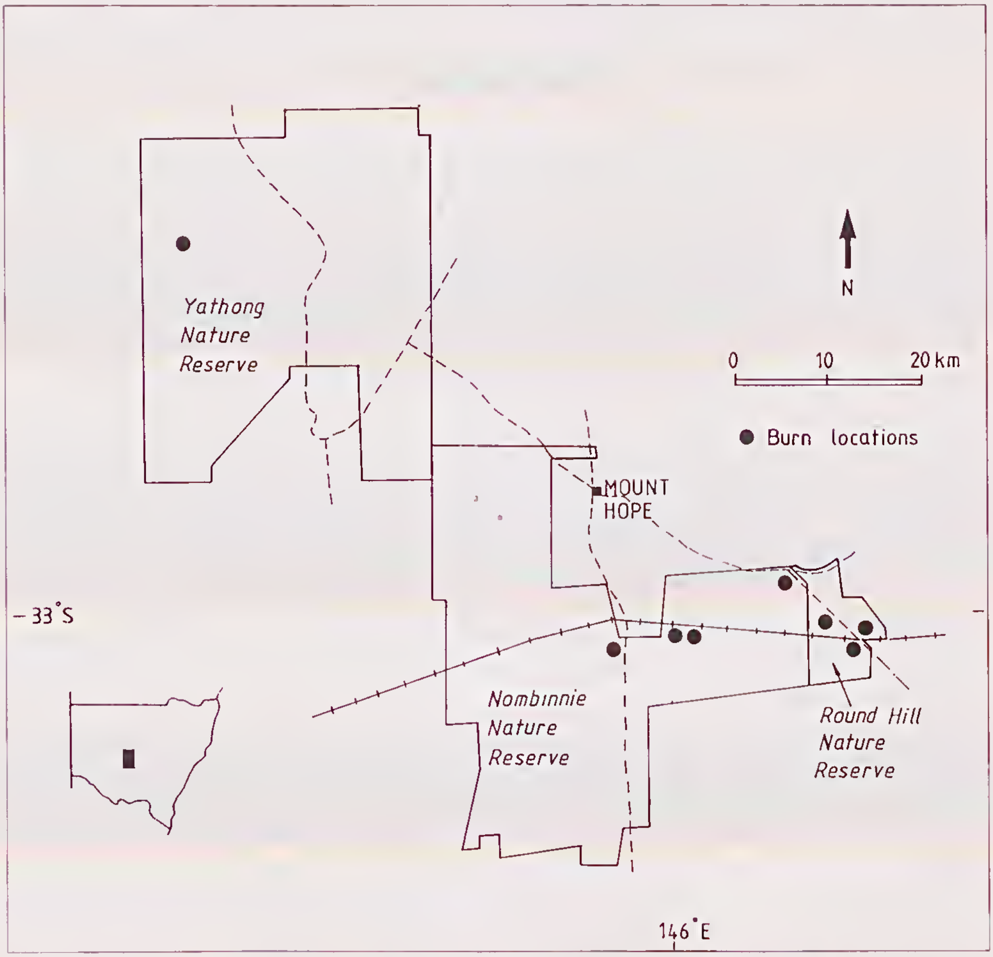

Figure 1. Location of the study areas in central-western New South Wales.

The fire treatments

In January and August 1992 we selected nine areas of mallee representing a broad range of fire histories. These areas represent times since last fire of 1, 3, 4, 7, 13, 16, 18, 35, and 100 years (Table 1). An additional block was measured 2 weeks after an experimental burn. Blocks varied in size according to fire history. Blocks at Yathong Nature Reserve (0, 1, 3 and 4 yrs) were either 100 X 100 or 200 X 200 m, and resulted from experimental fires (Bradstock et al. 1992). The 7, 13, 16, 18, 35 and 100 year fire histories were located on sites burned by wildfires and occurred over many hundreds of hectares. Fires in experimental blocks produced levels of fuel consumption and scorch in the vegetation that were visually similar to the study sites burnt by wildfires. Data for the 100 years since fire treatment were collected from three remnant areas of mallee dominated by *Callitris preissii* subsp. *verrucosa* located at Yathong (1 block) and Round Hill Nature Reserves (2 blocks). These remnant areas resulted from the progression of *Callitris preissii* subsp. *verrucosa* individuals from the understory into the overstorey, resulting in a diminution of fine fuel and hence fire frequency (Bradstock 1989, 1991). Time since fire in the these sites was indirectly estimated from size measurements of dominant *Callitris preissii* subsp. *verrucosa* individuals relative to younger plants of known age at other nearby sites (Bradstock unpublished data).

Measurements

At each site a transect was laid out through a homogeneous area of mallee, along which 20, 0.25 m^2 quadrats were systematically sampled at 10 m intervals. On the smaller experimentally burnt sites, transects were laid out along the two plot diagonals. Transects were located on the sandplain units except for the 100 year treatments which traversed the small rises. One observer estimated the total cover of cryptogams, and the relative contribution to total cover of moss, algae and lichens. Previous studies (Eldridge 1993) have verified the accuracy of this method for estimating species composition. We have no data however on the composition of various taxa on

Table 1. Changes in the composition (%) of moss, algae and lichen with time since last fire (years). n indicates the number of quadrats used in the calculations and sem is the standard error of the mean.

Time since fire (year)		Moss		Algae		Lichen	
	n	mean	sem	mean	sem	mean	sem
1	17	7.6	1.0	72.9	1.6	19.5	1.4
3	13	7.0	4.7	57.3	11.6	35.7	1.8
4	9	11.1	11.1	68.9	13.7	20.0	1.9
7	57	15.5	0.7	57.9	0.8	26.6	4.0
13	18	3.0	0.7	10.3	4.3	86.7	1.0
16	37	8.2	0.7	20.3	1.0	71.5	1.0
18	18	6.1	2.3	31.4	10.4	62.5	9.9
35	19	7.4	3.7	35.0	7.9	57.6	1.4
100	24	4.2	4.2	77.3	7.8	18.5	1.2

the plot at time zero. Apart from a general description of the main species found at the sites, we were only interested in broad cryptogamic taxa. Consequently cryptogams were pooled into either moss, lichens or algae.

Results

Fire resulted in a dramatic reduction in cryptogam cover from about 35% on a block last burned in 1985 (i.e. 7 years since fire) to 5% two weeks after fire. Cryptogam cover increased markedly with time since last fire, reaching a maximum of 52% at 16 years since fire. Cover then declined to < 2% at 100 years since fire. Within a single fire history, cryptogam cover was highly variable.

The moss flora at the sites was dominated by *Didymodon torquatus*, with smaller occurrences of *Bryum pachytheca, Desmatodon convolutus, Barbula hornschuchiana, Gigaspermum repens* and *Eccremidium pulchellum*. The lichen flora comprised *Endocarpum* spp., *Collema* spp. and *Psora decipiens*. Some other unidentified lichen and algae were present at the sites.

Mosses contributed very little to total cover, and their contribution to total cover was generally < 10% through time (Table 1). Composition of algae within the cryptogamic layer however was greatest shortly after fire (73% after 1 year), declining to low levels due to a gradual replacement by lichens (Figure 2). The 100-year-since-fire sites were dominated almost exclusively by algae, although total cover was < 2%. One-way ANOVA revealed no significant differences in composition of moss, lichen or algae due to the large spatial variation in composition between quadrats at any given site.

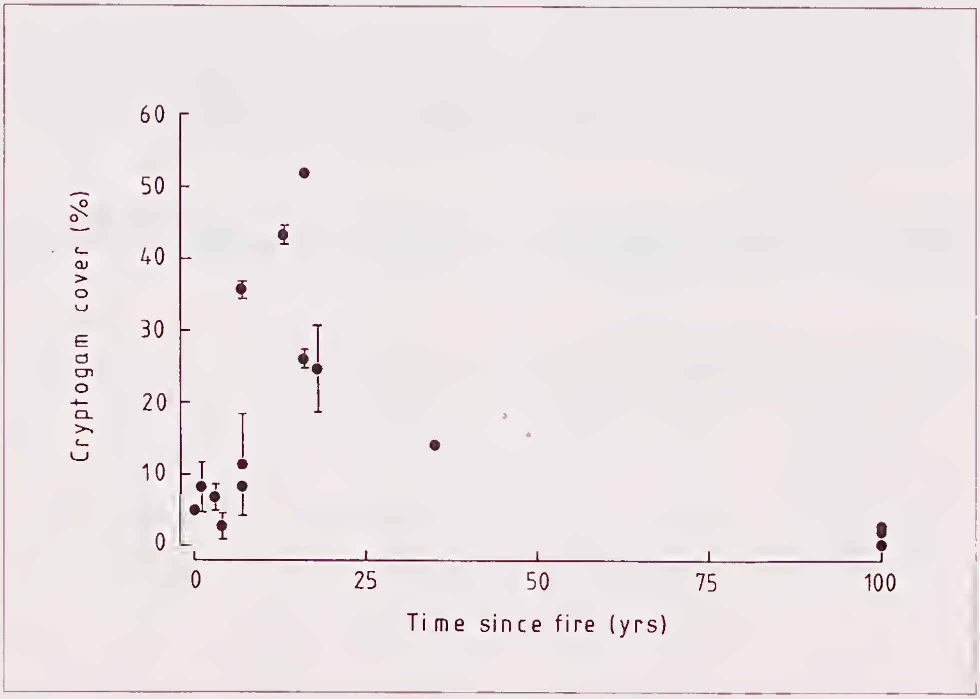

Figure 2. The relationship between total cryptogam cover (%) and time since last fire (years). Symbols enclose standard errors of the mean except where indicated.

Discussion

Non-vascular plants are primary stabilisers after major perturbations such as fire or grazing. In aeolian landscapes, where the post-fire soil surface is particularly unstable, largely due to saltating sand grains, little is known of the process of recolonisation by cryptogams after fire.

Effect of fire on total cover and composition

The results indicate that maximum cryptogam cover occurs 13–16 years after fire. At less than 7 years after fire, cryptogam cover is likely to be low (< 20%; Figure 1) and to be dominated by algae at the expense of lichen (Table 1). Fire failed to completely eliminate cryptogam cover on the plot measured two weeks after fire, as the main understory fuel *Triodia irritans* was only patchily distributed on the ground.

The only other data on post-fire recovery of cryptogams comes from studies on red earth soils in the semi-arid woodlands by Greene et al. (1990). These studies showed that cryptogam cover reached a maximum of about 60% four years after burning. This level probably represents the upper limit of cryptogam cover on red earth soils, and would be expected to decline in response to the development of stable cover of vascular plants. This maximum cover value is consistent with our observation of 52% for a sandy soil, but the time taken to achieve this was significantly greater in our study (13–16 years, Figure 1). Johansen et al. (1984) showed that there were still marked reductions in cover and frequency of moss, algae and lichen five years after burning. Similarly West and Hassan (1985) showed only partial recovery of moss and lichen from a Utah rangeland after 2 years. In a desert shrub community in Utah, Callison et al. (1985) reported that cryptogamic crusts had not recovered even 30 years after fire.

Greene et al. (1990) found that continual burning (yearly for 7 years) completely destroyed cryptogams. Micromorphological examination of the cryptogamic crust revealed that continual burning eliminated fungal hyphae and the gels cementing individual mineral particles together. In that study, fire led to a breakdown in the structural integrity and organic component of the soil crust, and to reductions in spatial heterogeneity at the soil surface. The slower recovery rates in our soils may have resulted from differences in lichen or algal taxa between the two sites (A. Downing pers. comm. 1993), due to different soil conditions between the two sites, or lower populations of fungi and blue-green algae in sandy soils. In a study of post-fire recovery of algal soil crusts in the USA, Johansen et al. (1993) observed that certain functional groups of algae were associated with specific soil pH levels. They postulated that these algal groups had different abilities to recover after fire. Differences in recovery might also have been due to the more hostile post-fire environment on the sandy soils which is dominated by wind-induced erosion.

The dynamics of cryptogam cover after fire is closely tied to their competitive advantage over vascular plants during the early stages of recovery, as well as their interaction with vascular plant recruits and the resprouting mallee shrub layer. During the first few years after fire in a eucalyptus shrubland, litter is generally low (Bradstock 1991), at which time algae are primary stabilisers of the soil surface. Blue-green algae have the capacity to fix atmospheric nitrogen, making this available to developing vascular plants (Rychert et al. 1978). Algal polysaccharides and fungal hyphae cement the soil particles into more stable units, providing a substrate for developing mosses and vascular plants. Coincident with an increase in nitrogen fixation and organic matter levels, mosses and lichens increase in cover. This increase in cryptogam cover up to a maximum at 16 years corresponds with an increase in cover of understorey shrubs and *Triodia irritans* (Bradstock 1989). Despite the dominance of these shrubs in the lower strata, and the density of mallee eucalypts in the overstorey (Bradstock 1991, Bradstock & Gill in press), there are still large patches of bare ground between the shrubs for colonisation by cryptogams. However, after about 16 years post-fire, our results suggest that cryptogam cover begins to decline. This can be attributed to the spreading of litter from overstorey *Eucalyptus* species and *Callitris preissii* subsp. *verrucosa,* which, in the absence of fire, reduces the cover of bare ground and thus niches for colonisation by cryptogams.

As well as changes in total cover due to fire, we found differences in the relative composition of moss, algae and lichen, although these differences were not significant due to the high spatial variability. Our results suggest that frequent burning (i.e. less than once every 7 years) leads to the persistence of algae at the expense of moss or lichen (Table 1). This is consistent with work by Schulten (1985), who found that fire reduced the composition of mosses and lichens during the initial stages of recovery on a sandy soil in the Midwest of the United States.

Implications for management of mallee landscapes

As mallee landscapes support pasture plants of low grazing values, carrying capacities are as low as one sheep to 20 hectares (Noble 1984). The use of controlled burning in mallee shrublands is restricted under Regulation 50C(1)(j) of the Western Lands Act 1901. Current legislation, however, allows burning in eucalypt shrublands for the purpose of promoting the growth of pasture species or for reducing fuel loads, provided that the dominant eucalypt species are not killed. Similarly, fire is used by park administrators for hazard reduction and habitat manipulation. Our results suggest that the cover and composition of cryptogamic crusts will be dependent on the fire regime adopted by land managers, and this may affect the vulnerability of the surface to erosion. For example, under a regime of frequent fires where algae are dominant, wind and water erosion may increase, particularly in the absence of a high cover of vascular plants. Tchoupopnou (1989) showed that algal-covered surfaces were the least effective and lichen the most effective at reducing erosion. Increased diversity of cryptogamic flora on plots of 10–15 years since fire would result in an adequate cover of mosses and lichens, maximising soil microtopography, increasing surface detention, and decreasing rainsplash and erosion. There is value in the proposition of Good (1981) that management should be flexible, allowing for long fire-free periods in reserves, which would aid plant species conservation. An alternative strategy may be to proscribe certain events which are incompatible with the fundamental aim of conservation (e.g. frequent fires), but allow others to happen (e.g. wildfires or no fires) according to chance (Bradstock 1989).

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Lost and found: *Nothofagus moorei* at Comboyne

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Bale, C.L.[1] & Williams, J.B.[2] ([1]New England Institute of TAFE, Armidale, NSW, Australia 2350; [2]Botany Department, University of New England, NSW, Australia 2351) 1994. Lost and found: Nothofagus moorei *at Comboyne.* Cunninghamia *3(3): 529–533.* A knowledge of the distribution and species associates of *Nothofagus moorei* (F. Muell.) Krasser is useful in elucidating the former distribution and significance of the species. Although previously thought to have been lost from Comboyne Plateau, *N. moorei* is now known to occur there in at least four small stands. The size distributions of *N. moorei* individuals and the floristics of these communities are reported together with a discussion of the significance of this extension to the known contemporary distribution of the species.

Introduction

Nothofagus is regarded as an ancient genus of great importance to Southern Hemisphere biogeography (Melville 1982, Hill 1992). *Nothofagus moorei* (F.Muell.) Krasser is a broad-leaved species of the subgenus *Lophozonia* (Hill 1992) and is one of the most geographically isolated species of the genus. This species occurs disjunctly on mountain, plateau, and escarpment positions in eastern Australia between the Barrington Tops area (latitude 32° 03′ S) and the Lamington Plateau (latitude 28° 15′ S). Floyd (1989) lists most of the known locations of *N. moorei* in New South Wales.

A detailed knowledge of the contemporary distribution of *N. moorei* is useful in several ways. As noted by Melville (1982), the present distribution of the genus is important in elucidating not only its former significance and distribution, but also in making broad paleoclimatic and paleobiogeographic inferences. At the species level, Bale and Williams (1993) showed that distributional and floristic data were useful in elucidating the refugial status and classification of communities dominated by *Nothofagus moorei*. Further, to achieve the kind of morphological and genetic data called for by Hill (1992), it is desirable to sample throughout the known range of *Nothofagus* species. An account of previously unknown contemporary occurrences of *N. moorei* on the Comboyne Plateau is thus warranted.

The Comboyne Plateau (Figure 1), centred on latitude 31° 36′ S and longitude 152° 28′ E, is a scarp-bounded paleoplain remnant located between the Great Escarpment and the seaboard on the central north coast of New South Wales (Pain & Ollier 1986). The plateau forms a low ramp from 450 m elevation in the north to about 700 m at the southern rim. Tertiary basalts overlie much of the plateau surface, giving rise to generally fertile krasnozemic soils. In the southern third of the plateau, some of the basaltic mantle has been removed, exposing the underlying Triassic sediments of the Lorne Basin. Drainage lines form a typical radial pattern. The Thone River, flowing north, and Mumfords Creek, flowing west, drain the largest catchments of the plateau surface.

The former natural vegetation of the Plateau was mostly ‘Softwood Brush’ (Chisholm 1925); now described as Subtropical Rainforest (Baur 1965) or Complex Notophyll Vine Forest (Webb et al. 1984). Almost all of the original vegetation was removed in the first quarter of this century, particularly from those parts of the plateau surface and benches where soils were richest. Only small samples of the original rainforest

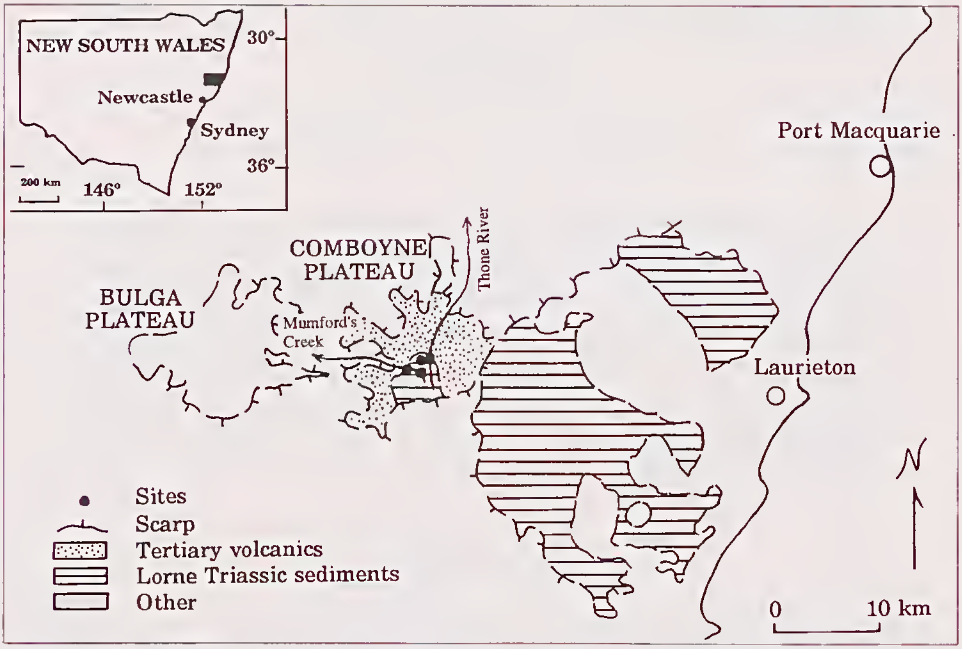

Figure 1. Location and geomorphology of the Comboyne Plateau and surrounding area (after Pain & Ollier 1986).

Table 1. Descriptions of four *Nothofagus moorei* sites at Comboyne

	Site 1	Site 2	Site 3	Site 4
Location	Thone River	Thone tributary	Mumfords tributary	Mumfords Creek
Site description	Surrounded by pasture. Cleared early 1900s.	Surrounded by pasture. Cleared early 1900s.	Stream-side remnant surrounded by pasture. Cleared early 1900s.	Stream-side rainforest with large relic individuals. Some Coachwood extraction since 1940s.
Aspect	Level stream terrace	Level stream terrace	W	S
Altitude (m)	580	600	620	590
Stand size (m^2)	200	200	1000	5000

Table 2. Floristic richness of four *Nothofagus moorei* sites at Comboyne

Lifeform	Site 1	Site 2	Site 3	Site 4
Trees & Shrubs	$12(2^a)$	$16(4^a)$	$23(1^a)$	$27(3^b)$
Lianas		0	$2(1^a)$	$1(1^a)$ 5
Epiphytes	1	4	2	8
Herbs	$2(2^c)$	$7(6^c)$	$8(6^c)$	(4^c)
Total	15	28	34	47

[a]Introduced; [b]Marginal; [c]Ferns.

cover remain, of which the stands at Boorganna Nature Reserve and Hills Brush are most notable.

The pioneering botanical survey of Comboyne by Chisholm (1925) is significant in many respects, but our attention was particularly drawn to his mention of '*Fagus moorei* (Negrohead Beech), which is extremely rare, although many trees were undoubtedly destroyed during clearing'. In recent years, the elusiveness of *Nothofagus* [Fagus] *moorei* has led some authors to the conclusion that it no longer survives at Comboyne. Based on the evidence of some associate species, Floyd (1990) surmised that *N. moorei* may have previously occurred on Mumfords Creek. Adam (1992) concorded that 'The absence (of *N. moorei*) from the Bulga and Comboyne Plateaux is explained by clearing early in the twentieth century'.

Recent investigations

During the past four years, several searches of selected parts of the Comboyne Plateau were made by us. Given the gallery rainforest habitat of *N. moorei* at similar altitudes at East Dorrigo, efforts were directed at searching similar sites at Comboyne. Searches of the southern and eastern escarpment of Comboyne and of the adjoining Bulga Plateau were also made. With the help of local residents we were able to discover that *Nothofagus moorei* still occurs on the Comboyne Plateau and to date four stands of *N. moorei* have been located. All are in gallery positions in the southern half of the Plateau. These range in size from two adjacent trees in otherwise cleared pasture to a relatively intact stand of more than 20 mature trees together with many juveniles and a range of associate species. Herbarium specimens NE 057405, NE 057406, and a duplicate lodged at the National Herbarium of NSW were collected at the latter site. In areas of apparently suitable environmental conditions on Bulga Plateau, no *N. moorei* occurrences have yet been found.

All four sites on the Comboyne Plateau were found high in the catchments of Mumfords Creek and the Thone River at elevations of between 570 and 630 metres (Table 1). Our observations indicated that none of the sites occurs directly on the basalt-derived eutrophic soils. Rather they occurred on soils derived from either the Lorne Basin sediments, or the contact between these rocks and the overlying volcanics. It was likely however that at some sites soils contained basaltic contributions from upslope caprock. At these relatively low altitudes, it appeared that the gallery positions of sites are critical in providing *N. moorei* with cool moist micro-climates and abundant soil moisture.

Site floristics

Species lists were compiled at all sites, and a summary of floristic richness is presented in Table 2. Vascular species richness increased with stand size, although the number of species of trees and shrubs differed little between the two Mumford sites, despite marked differences in site histories. Substantial numbers of liane and epiphyte species occurred only at Site 4 (Mumfords Creek), indicating that this site has attained a greater structural integrity than the others. At all sites, ferns dominated the herb stratum.

At Site 1 (Thone River), the only tree species associating with *N. moorei* were *Tristaniopsis collina*, *Acacia melanoxylon* and *Callicoma serratifolia*. *Doryphora sassafras* occurred as an occasional sapling. Site 2 (Thone tributary) was similar to Site 1, although the shrub layer was floristically richer and *Callicoma serratifolia*, although locally abundant, was absent from the stand. *Lomatia arborescens* was the most prominent small tree at this site. Much of the nearby streambank was infested with exotic species such as *Ligustrum sinense* and *Solanum mauritianum*, and these species had invaded the small *N. moorei* stand. Much of the floristic complement of Site 2 was also present at Site 3 (Mumfords Creek tributary), together with many typical temperate rainforest species such as *Caldcluvia paniculosa* and *Schizomeria ovata*. Several small tree species of differing rainforest affinities occurred here too, including *Cryptocarya glaucescens*, *Lomatia arborescens* and *Backhousia myrtifolia*. *Cyathea australis* and *Todea barbara* were important shrubs. All of the foregoing species occurred at Site 4. At this location however, *Ceratapetalum apetalum* was codominant, and attained sole dominance in surrounding areas where *N. moorei* was absent. A feature of the floristics at Site 4 was the mix of species of microthermal and mesothermal affinity. *Quintinia sieberi*, *Alyxia ruscifolia* and *Orites excelsa* are typical associates of *N. moorei* at considerably higher altitudes, yet here they occurred with mesothermal elements such as *Guioa semiglauca* and *Platycerium bifurcatum*. Common species typical of these mid-altitude sites on oligotrophic and mesotrophic soils included *Cryptocarya meissneriana* and *Acradenia euodiiformis*.

Significance

The rediscovery of *N. moorei* at Comboyne is not significant in a historic biogeographic context; it has long been regarded as a former element of Comboyne rainforests. However, this find is important for other reasons. Firstly, it extends the contemporary distribution of *N. moorei* and provides some evidence that the species is of sufficient vagility to survive severe disturbance and fragmentation, despite here approaching its lower altitude limit and being somewhat remote from other populations. Secondly, it appears that at Comboyne *N. moorei* is fastidious in its site requirements, particularly in relation to site conformation. It is thus unlikely that *N. moorei* had extensive occurrences in the area. The impact of clearing and logging appears to have been in fragmenting perhaps already discontinuous ribbon-like galleries of these rainforests stands. In these situations *N. moorei* forms essentially stable assemblages with species of differing rainforest affinities. Many of these species are known to occur preferentially on oligotrophic and mesotrophic soils (Floyd 1990), or to have rather broad edaphic tolerances. The only other region known to us in which *N. moorei* routinely occupies similar topographic positions with a similar floristic complement is at East Dorrigo (Bale & Williams 1993).

Thirdly, at least two of these stands of *N. moorei* are of importance because they demonstrate a considerable dependence on seedling recruitment (Table 3). Whilst many old relic individuals are multistemmed or support well-developed coppices, field checks have established that a substantial component of the younger cohorts were seedling-derived. It appears that under the disturbance regimes at Comboyne, site conditions promote successful *N. moorei* seedling responses. The spread of individuals through seedling and juvenile cohorts suggests that positive seedling responses have occurred over many decades. We expect that seedling recruitment will diminish as disturbance-recovery proceeds and that individual replacement will then be maintained by coppicing.

Finally the stands of *N. moorei* at Comboyne are notable in that they represent a second low-altitude domain of the species. To our knowledge, the only other area in which *N. moorei* occurs below 650 m elevation is at East Dorrigo (Bale & Williams 1993). Whether or not any significant genetic differences occur between these low altitude populations and the much larger populations of the high plateaus and escarpment areas of northern New South Wales is currently being investigated. Should it eventuate that the extent of *N. moorei* forests is diminished by climatic change, then these low-altitude populations may be useful, both as *in situ* indicators of change, and as a genetic resource which might migrate to higher elevations.

Table 3. Numbers of individuals in size cohorts, largest individuals, and abundance of coppices in *Nothofagus moorei* stands at Comboyne (seedlings and some saplings verified as genets)

	Site 1	Site 2	Site 3	Site 4
Size Cohort				
Mature (> 20 m tall)	2	2	8	23
Semi adult (10-20 m)	0	0	5	19
Sapling (2-10 m)	0	0	> 40	21
Seedling (< 2 m)	0	2	8	5
Diameter of largest individual (cm)	60	26*	70	150
Relative abundance of coppices	—	+	++	+++

* Largest stem of multi-stemmed individual

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Observations on the ecology and conservation status of the rare herb *Gentiana wingecarribiensis*

P.G. Kodela, T.A. James and P.D. Hind

P.G. Kodela, T.A. James & P.D. Hind (Royal Botanic Gardens, Sydney NSW Australia 2000) 1994. Observations on the ecology and conservation status of the rare herb Gentiana wingecarribiensis. Cunninghamia *3(3): 535–541. Gentiana wingecarribiensis* L. Adams (Gentianaceae) is a rare, short-lived herb endemic to Wingecarribee Swamp in the NSW Central Tablelands (34° 34′ S, 150° 31′ E). Population estimates were made over two seasons and observations on distribution, growth and habitat recorded. Population numbers are low, with the Gentian restricted to a narrow ecotone area on the swamp margin. Specific regeneration requirements, poor seed dispersal and lack of competitiveness may help to explain its rarity. The survival of *G. wingecarribiensis* depends largely on protection of the ecotone area between the swamp and surrounding grassland, particularly from extreme and/or sudden changes in water level. Management strategies and recommendations are provided.

Introduction and methods

Gentiana wingecarribiensis L. Adams (Gentianaceae) is a small, short-lived annual or ephemeral herb recorded only from Wingècarribee Swamp (34° 34′ S, 150° 31′ E), about 5 km WNW of Robertson on the Central Tablelands of New South Wales. It was first reported in the early 1960s by A.R.H. Martin, with herbarium specimens collected during November 1967 by P. Bates, and L.A.S. Johnson and B.G. Briggs. Further collections were made in 1971 and 1973, and it was described by L.G. Adams in Adams & Williams (1988). It was not, however, until 1992 that new interest emerged and it was found again by P.D. Hind and colleagues of the National Herbarium of NSW and the NSW National Parks & Wildlife Service.

Gentiana wingecarribiensis is assigned a conservation status code of 2E in the Australian rare or threatened plant list (Briggs & Leigh 1988). The 2 implies the species has a geographic range less than 100 km; E implies it is considered to be endangered with a serious risk of becoming extinct over the next few decades. In view of the threatened status of *G. wingecarribiensis*, a brief study was undertaken to compile further information on its distribution and ecology. Using site information from herbarium collections and communications with several past collectors, suitable areas were searched at Wingecarribee Swamp. Population estimates and observations relating to distribution, stage of growth, associated species and habitat characteristics were made for each site. Potential sites in other wetland habitats in the district were also briefly searched.

Plant description

Gentiana wingecarribiensis is an erect, glabrous herb to 11 cm high in flower, with opposite, ovate, sessile leaves 2–9 mm long. The 1–9 flowers are solitary, terminal and usually open in succession over a period of 2–3 months from October. Opening of the corolla (anthesis) occurs in bright sunlight (photonastic) and/or possibly as a response to change in temperature (thermonastic). The corolla is narrow-campanulate, 10–17 mm long, greenish-ribbed outside and purple-blue inside (Fig. 1). The distinctive capsule has a flared, 2-lipped apex (Fig. 2); seeds are numerous, 0.25–0.35 mm long. More complete descriptions are provided by Adams & Williams (1988) and Harden (1992).

Gentiana wingecarribiensis is one of four species of *Gentiana* recorded in Australia, all belonging in *Gentiana* section *Chondrophyllae* Bunge. This is a typically montane and predominantly Northern Hemisphere group, the southern limit of which is significantly extended by the Australian species (Pringle 1979, Adams & Williams 1988). All four species occur on the New South Wales tablelands and are considered endangered or vulnerable (Adams & Williams 1988).

Distribution and site characteristics

Wingecarribee Swamp is a large, montane peatland or fen at 680 m alt., supporting a complex of vegetation types and diverse flora (Hope & Southern 1983, Kodela & Hope 1992). The catchment is predominantly of Triassic Wianamatta Shale overlying Hawkesbury Sandstone with Tertiary basalt-capped hills mainly in the east.

In November 1992 three discrete, localised populations of *G. wingecarribiensis* were recorded on the southern side of the swamp. They were located in an ecotone area within 5–10 m of the swamp margin where the sedgeland, with some low shrubs, intergrades with the surrounding grassland/pasture. This micro-habitat on damp peat or peaty loam to clay loam supports a low, open vegetation cover 5–60 cm high, of predominantly sedges, grasses and other herbs, as well as woody subshrubs (Fig. 3). The soil was damp or occasionally saturated, but standing water was not evident. Earlier herbarium collections refer to a micro-habitat of low *Sphagnum* hummocks and at one of the three sites this was evident, the remaining sites being level ground. At one site there was marked disturbance from cattle trampling on the swamp periphery. Associated species included *Asperula* cf. *gunnii*, *Baumea rubiginosa*, *Carex* species, *Centella cordifolia*, *Comesperma retusum*, *Dichelachne inaequiglumis*, *Dichondra repens*, *Drosera peltata*, *Eriocaulon scariosum*, *Hydrocotyle peduncularis*, *Hypericum japonicum*, *Juncus planifolius*, *Leptospermum obovatum*, *Myriophyllum simulans*, *Prasophyllum uroglossum*, *Pratia surrepens*, *Pultenaea divaricata*, *Schoenus apogon*, *Thelymitra pauciflora*, *Themeda australis*, *Viola caleyana*, *Viola* species A (*V. hederacea* subspecies *fuscoviolacea*), *Wahlenbergia ceracea*, and the introduced species *Anthoxanthum odoratum*, *Holcus lanatus*, *Hypochaeris radicata*, *Lotus uliginosus*, *Sisyrinchium* species A and *Trifolium* species.

Much of the swamp is apparently unsuitable for *G. wingecarribiensis* due to a dense sedgeland or reedland cover and/or too high water levels. It has not been found at other potential sites in wetland habitats in the district, including Wildes Meadow, 4.5 km south of Wingecarribee Swamp, which has the most comparable environmental conditions.

Population size and biology

The location of individuals and estimation of population sizes is made difficult by the small inconspicuous appearance of the plants, the short life span of individuals and the flowers only opening in bright sunlight. During November–December 1992 the three identified sites had estimated populations of 36, 6 and 50 plants (estimates made by the NPWS were slightly higher, Cohn undated). The observed populations were highly localised, in areas of approximately 3 m x 3 m in sites 1 and 2 and c. 15 m x 3 m in site 3. Sites 1 and 2 were approx. 30 m apart, while site 3 occurs

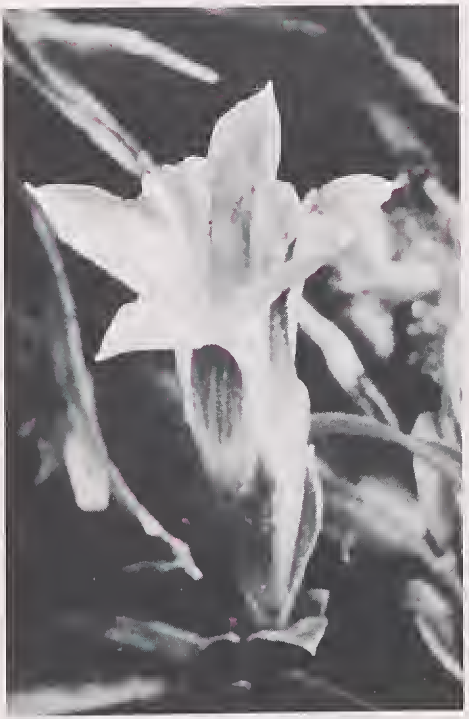

Figure 1. *Gentiana wingecarribiensis* flowers over a period of 2–3 months from October. The corolla is only known to open in bright sunlight. All photos this page by D.W. Hardin.

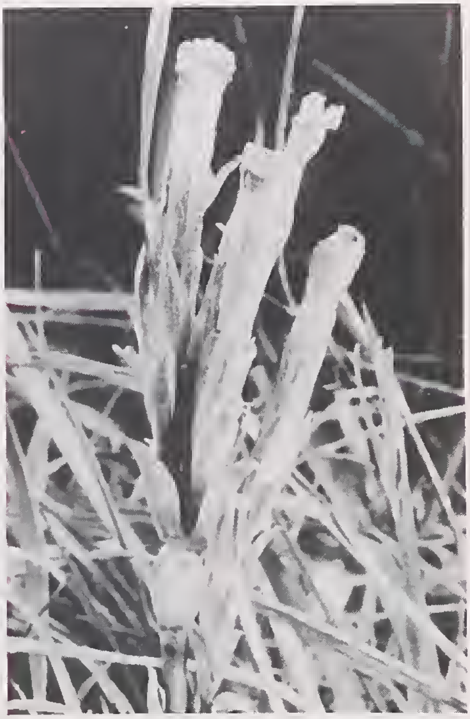

Figure 2. The distinctive capsule of *Gentiana wingecarribiensis*.

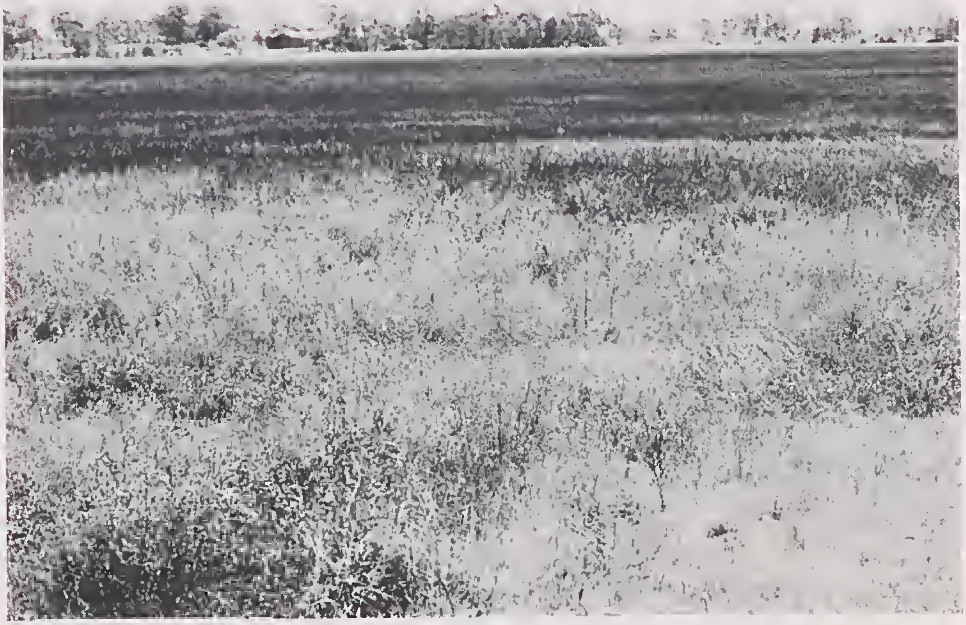

Figure 3. *Gentiana wingecarribiensis* is now restricted to a narrow ecotone area on the margin of Wingecarribee Swamp where the vegetation is low in stature and relatively open.

c. 1.75 km due WNW of these sites. The individual plants had a scattered distribution within these sites. The Gentian was absent from adjacent areas with apparently similar habitat conditions.

In early November 1993 the estimated population at site 1 was approx. 30 plants. Individual plants were close to the previous year's population, indicating seeds are very locally dispersed. No plants were evident at the other known sites at this time or later in the season.

Gentiana wingecarribiensis flowers chiefly from October to December, but it was seen flowering in January 1988 (R. Bates pers. comm.). From our observations, flowering occurs in plants from 2.5 cm high, considerably shorter than the surrounding vegetation. Individual plants may have buds, flowers and capsules present at the same time. The capsules and seed appear to mature rapidly within about 1 month of flowering and the plants wither and die completely within about 2 months.

Land-use history

All the recorded sites for *G. wingecarribiensis* appear to be either on freehold land or on the border of freehold land and the swamp, which was acquired by the Water Board in June 1993. Although the sites are within an area zoned for Environmental Protection (Cohn undated) there is no control over agricultural use. The western part of the swamp was flooded in the mid-1970s for a reservoir, which is managed by the Water Board to supply water to local towns and occasionally Sydney. Drainage channels on the swamp are associated with mining and agricultural activities. Peat mining operations have been active in the western part of the remaining mire over the last 20 years. Surrounding slopes in the catchment are used for grazing of beef and dairy cattle. As a result of human disturbance and pasture improvement, there are many exotic plant species that occur mainly on the swamp margins and surrounding land. Much of the swamp vegetation appears to be subject to annual burns, usually in late spring, though several fires may occur in a year. The fires are often patchy, and observations suggest that the Gentian sites are mostly not affected.

Discussion

Despite the difficulties encountered in estimating the frequency and distribution of *G. wingecarribiensis* and the short period of observation, recent field assessments appear to confirm that the species is restricted to Wingecarribee Swamp and that population numbers are low. More specifically, the plant is restricted to a relatively narrow ecotone area on the swamp margin where the vegetation is low in stature and relatively open.

Despite the production of large quantities of seed in 1992 (hundreds of seeds are produced per capsule), low population numbers at site 1 in 1993 indicate either a low percentage germination or low seedling survival rate. These observations and the absence of germination at the other sites in 1993, suggest that seed may be stored in a persistent soil seed bank. Seeds of the European species *Gentiana verna* remain viable until the second season when germination is often better than the first (Elkington 1963). Overseas studies on *Gentiana* also indicate that a cold phase (e.g. freezing) is required for germination (Simmonds 1946, Elkington 1963). The germination requirements of *G. wingecarribiensis*, however, need further investigation.

The rarity of *G. wingecarribiensis* may be explained by a combination of factors. The highly localised populations and fluctuations in population numbers suggest that regeneration requirements for the species may be very specific. If local environmental conditions are unsuitable the seed may experience some degree of enforced dormancy. The ability to remain dormant in the soil for long periods is a recognised feature of plants inhabiting unstable environments (Fenner 1985), including swamps which experience fluctuations in water level. Under Raunkiaer's life-form classification *G. wingecarribiensis* is a therophyte, i.e. 'a plant that completes its life cycle rapidly during periods when conditions are favourable and survives unfavourable conditions (e.g. cold, heat, or competition) as seed' (Allaby 1992). The viability of populations will be further affected if plants are unable to successfully exploit potential sites. The appearance of individuals at site 1 in 1993, in the close vicinity of the previous year's population, suggests a clumping effect consistent with limited seed dispersal, though the minute and lightweight seed of *G. wingecarribiensis* might be conducive to wind dispersal. Pringle (1979) suggests that seeds of certain species of *Gentiana* could be dispersed as the wind shakes the open capsules. The low height of *G. wingecarribiensis*, however, may limit the effectiveness of this dispersal method in the absence of air turbulence. When the capsules are open in wet weather, seed dispersal could be assisted by rain-splash. Once seeds have left the capsules, there may be a possibility for lateral water dispersal if the watertable is above the ground near the plants at the time of fruiting or if they occur near local ponds or channels on the swamp. There are several records of *G. wingecarribiensis* occurring near the edges of channels.

Rapid plant growth and seed production is apparent, *G. wingecarribiensis* completing its life cycle in approx. 3 months. It is feasible that strong selection pressures could operate in favour of such rapid development considering the small size of the plants and their dependency on bright sunshine for anthesis. The early flowering period may have evolved to ensure optimal conditions before the later growth flush of taller sedges and grasses. In early December 1992 one population was located in relatively dense stands of *Themeda australis* and other herbs to 60 cm high, but only one month later no Gentian plants could be found.

Conservation and management

The long-term survival of *G. wingecarribiensis* is likely to depend on the maintenance of the micro-habitat found in the ecotone area of the swamp. Adams & Williams (1988, p. 168) state that 'viable populations are probably dependent on a stable habitat of short, damp turf of forbs, sedges, grasses and bryophytes' and 'its long-term survival could depend on the watertable remaining relatively high and fluctuating only within limits of a few centimetres for lengthy, and possibly critical, seasonal periods'. Prior to European settlement, grazing by native herbivores may have played an important role in maintaining short, open conditions in this type of habitat (Adams & Williams 1988). Today, over-grazing and trampling by cattle, as well as ground disturbance caused by heavy machinery such as tractors would be detrimental to such sites, particularly during the plant's growing season. Potential Gentian habitats have already been lost on the edges of the swamp where intensive trampling has created muddy, rough surface conditions.

Disturbance by fire or physical means, in the absence of grazing by native herbivores, may be a necessary management tool to reduce competition with other species, including weeds, and to promote an open vegetation structure that provides sufficient light and shelter for the Gentian. Such management recommendations were made by Bishop (1992) as a result of a survey of the rare orchid *Prasophyllum uroglossum* which also occurs in this ecotone area of the swamp. A report of *G. wingecarribiensis* flowering on recently burned peat mounds late in the season (R. Bates pers. comm.), when sites may normally be overgrown with other species, supports this view. A fire shortly before the Gentian's growing season or subsequent to completion of fruiting could be beneficial; however, if the fire coincides with the flowering and fruiting stages the plants are likely to be killed.

Current land-use practices, i.e. peat mining, agriculture and use of part of the swamp as a reservoir may threaten the survival of *G. wingecarribiensis*. Major alterations in the watertable or changes in the hydrological regime, as well as grazing pressure and competition from exotic plant species appear to be the most critical factors. The Gentian appears to be sensitive to changes in water level and may have occurred more widely in areas now flooded by the reservoir. Damming would have also increased watertable levels in the remaining swamp, which may have affected the distribution of *G. wingecarribiensis*. This is supported by observations made by Martin (pers. comm.) in the early 1960s, which indicate that the Gentian was growing in central parts of the swamp prior to construction of the reservoir. Peat mining, drainage and cattle grazing and trampling, directly or indirectly, threatens the remaining suitable habitat. Changes in water quality and soil nutrient status are likely to have resulted from agricultural practices and peat extraction. The impacts of these changes on the Gentian and other wetland species need investigation.

The ecotone between the swamp and the grassland/pasture is of considerable conservation value, not only for the survival of *G. wingecarribiensis* but also for the rare and endangered *Prasophyllum uroglossum*, which also appears to be restricted to Wingecarribee Swamp. Additionally, species diversity is high in the ecotone as it is an overlap zone between two communities and may provide a refuge for marginal swamp species. The conservation of *G. wingecarribiensis* will depend on protecting its habitat in the ecotone area, including the maintenance of a buffer zone.

Management strategies and recommendations

Further investigation of the ecology of *G. wingecarribiensis* is warranted, particularly by monitoring population numbers over several years and investigating the impacts of burning and other land-use practices. To assess the long-term viability of the species, the size and longevity of the soil seed bank requires investigation. Seed germination trials should continue at Mount Annan Botanic Gardens and self-perpetuating populations be established in accordance with the Royal Botanic Gardens Plant Conservation Policy (Royal Botanic Gardens 1993). Considering the small size of populations at Wingecarribee Swamp, further collections should be limited and the impacts of human trampling associated with field studies considered.

The recorded sites of *G. wingecarribiensis* should be fenced for protection from grazing and trampling. Additional areas with similar habitat conditions could also be managed as potential Gentian sites. While grass mowing and slashing may be useful in maintaining open sites, such practices should be avoided during the Gentian's growing season i.e. October–January. The control of exotic plant species in these areas is important. The Blackberry *Rubus discolor*, for example, occurs on swamp margins near the Gentian sites. Methods for the control of woody weeds are outlined in Cohn (undated).

The survival of *G. wingecarribiensis* depends largely on protection of the swamp from extreme and/or sudden alterations of water levels resulting from land-use activities in the catchment. Watertable levels should be monitored and consideration given to the potential impacts of any manipulation of water levels and future works in Wingecarribee Reservoir. Any future expansion of the reservoir onto the swamp could result in the loss of habitats crucial to the survival of *G. wingecarribiensis*. The designation of Wingecarribee Swamp as a nature reserve, including a buffer zone, is recommended to increase protection of this rare and endangered species and the associated wetland communities.

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Floristics, structure and diversity of natural vegetation in the O'Hares Creek catchment, south of Sydney

David Keith

Keith, David, (NSW National Parks and Wildlife Service, PO Box 1967, Hurstville NSW Australia 2220) 1994. Floristics, structure and diversity of natural vegetation in the O'Hares Creek catchment, south of Sydney. Cunninghamia *3(3): 543–594.* Fifteen plant communities were described and mapped at 1:25 000 scale in O'Hares Creek catchment. Cluster analysis and ordination were used to elucidate relationships between the vegetation and environmental variables. Three forest communities and one scrub community occurred on relatively fertile, well-drained soils; three woodland and three heath communities occurred on less fertile, well-drained to damp soils; and five swamp communities occurred on periodically waterlogged soils of varying fertility. Floristic composition and vegetation structure were related to a complex of factors reflecting soil fertility and moisture status, as well as a regional rainfall gradient related to elevation and distance from the coast.

Of 510 vascular plant taxa recorded, 17 are listed as rare or threatened nationally and a further 24 are of regional conservation significance. The exotic flora is small (34 taxa recorded) and locally restricted to disturbed sites. While most of the plant communities have analogues in other parts of the Sydney sandstone area, their floristic composition is particular to the Nepean ramp, an area not well sampled by existing conservation reserves. The O'Hares Creek area and other water catchment areas, which cover much of the Nepean ramp, are therefore an important augmentation to the formal reserve system.

Introduction

Emerging from pastoral country around Appin on 21 October 1818, Allan Cunningham, then King's Botanist, remarked, 'we arrived at once upon an entire change of country, of a rugged sandstony character, alternated by extensive tracts of spongy bogs' (Lee 1925). Cunningham's sketch aptly captures a landscape that subsequently attracted numerous botanists to the area. Among them were Joseph Henry Maiden, a former Director of the Royal Botanic Gardens in the early 1900s, and Consett Davis, one of Australia's early students in classical plant ecology. Their publications, notes and collections contributed to early knowledge of the flora.

In recent years, the O'Hares Creek catchment is increasingly the focus of competing land-uses including nature conservation, mining, military activities, water supply and recreation. Conflicts between these land-uses are unlikely to be resolved rationally without a more thorough inventory of the biota than that provided by early work. This information, together with an evaluation of the regional significance of the biota, is required as a basis for ongoing management and conservation planning in the expanding southern Sydney–Wollongong–Campbelltown region.

This paper aims to describe the floristics, structure, diversity and habitat of plant communities, map their distribution, identify major environmental factors influencing vegetation patterns and evaluate the regional conservation significance of vegetation in the O'Hares Creek catchment.

Study area

The O'Hares Creek catchment, an area of 9 000 ha, is centred on latitude 34° 14' S and longitude 150° 52' E, 45 km south-west of Sydney centre (Figure 1). The area comprises part of the Nepean Ramp, which is in turn, part of the Sydney Basin. The 'ramp' is a dissected plateau dipping gently north-west away from the Illawarra escarpment toward the Cumberland Plain. The major watercourses, O'Hares and Stokes Creeks, both flow from elevated, low-relief terrain in the south-east to more dissected terrain in the north-west. Elevation varies from 100 to 450 m above sea level.

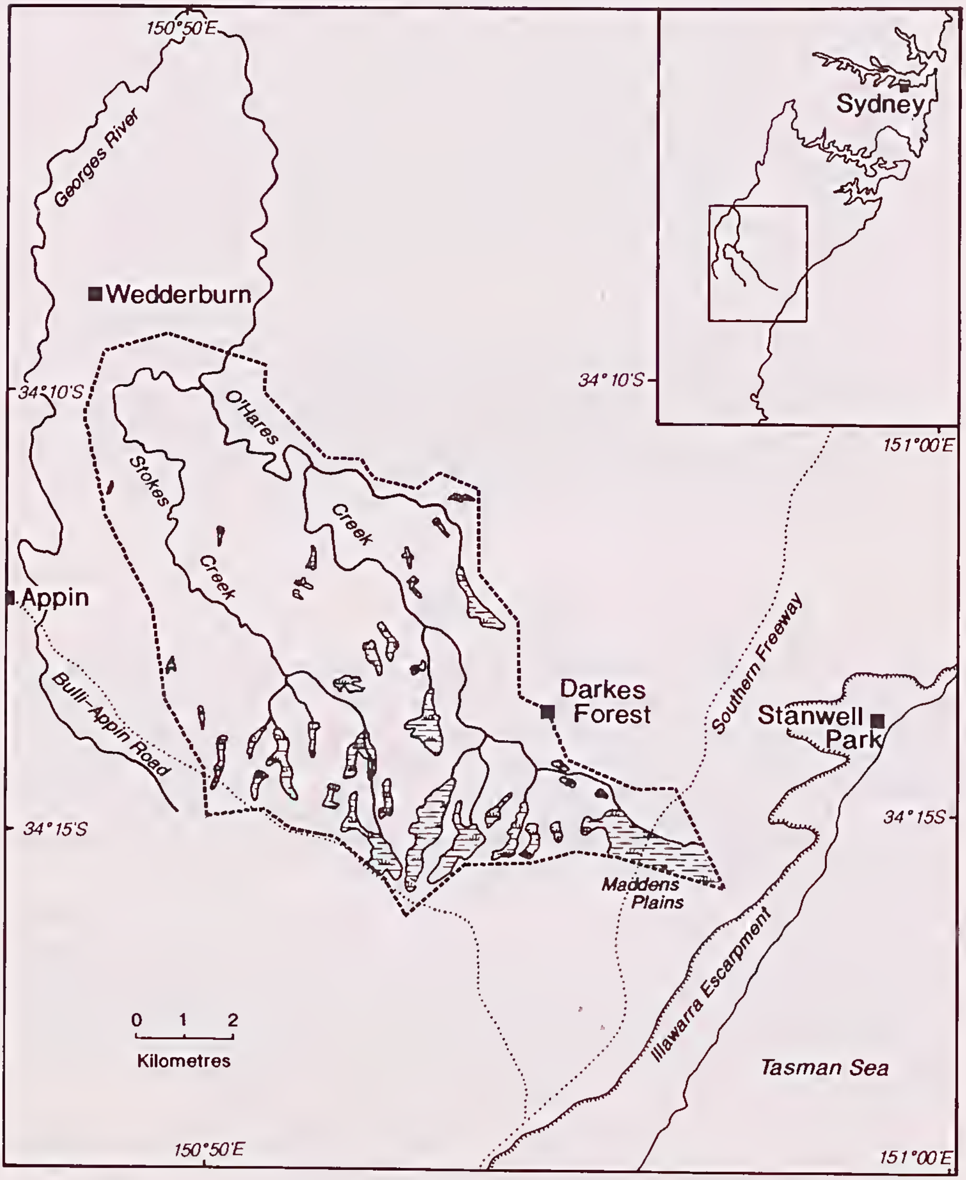

Figure 1. Location of O'Hares Creek catchment (from Keith & Myerscough 1993).

The Triassic Hawkesbury Sandstone Formation, the major geological unit of the plateau, is composed primarily of quartzose sandstone, but also includes lensoidal shale strata that outcrop in the eastern part of the catchment (Bowman et al. 1986). Thick ironstone mantles are present in some areas and may be the remnants of heavily weathered shale lenses (Sherwin et al. 1986). Deposits of swamp alluvium have accumulated in low-relief headwater valleys on the plateau (Young 1986a). The Hawkesbury Sandstone is underlain by the Triassic Narrabeen Group and the Permian Illawarra Coal Measures, respectively, which are exposed on the Illawarra escarpment. The Triassic Wianamatta Group overlies the Hawkesbury Formation and outcrops on the Cumberland Plain to the west.

The local climate is dominated by the influence of the Illawarra escarpment and the close proximity of the sea. There is a marked gradient in mean annual rainfall and seasonality from 1550 mm at Maddens Plains in the east to 850 mm at Wedderburn on the western edge of the catchment. An average annual evaporation rate of 800 mm at nearby Cataract Dam suggests a considerable moisture surplus in the east (unpubl. data, Bureau of Meteorology). At Maddens Plains, the wettest months are February and March, while September is the driest. Wedderburn has no obvious seasonal trend in rainfall. Rainfall also varies considerably from year to year, the range at Maddens Plains being 960–2550 mm. Temperatures vary from an average daily maximum of 25.9°C (January) to a minimum of 6.6°C (July) at Lucas Heights, 15 km north of the study area.

A major land-use on the Woronora Plateau is water catchment and supply, with the Sydney Water Board controlling five major dams. O'Hares Creek was set aside in the 1920s for this purpose but, unlike adjacent catchments, plans for impoundment of the creek were abandoned. The Water Board currently manages the area to maintain water quality by limiting development and restricting access. O'Hares Creek maintains a reliable supply of clean water to the Georges River, a major recreational waterway in southern Sydney. Coal is mined from the Bulli seam, 450–500 m below ground surface. Major coal processing plants and stock piles are located just to the west of the study area on the upper Georges River. Ventilation shafts and seismic survey lines have been constructed within the study area, resulting in localised disturbance. Other extractive industries within the catchment include small quarries for clay and sand, but these are now largely abandoned. O'Hares Creek catchment is used as a training area by the Australian Army as a supplement to Holsworthy Military Area which lies adjacent to the north. Orchards and hobby farms occupy shale-capped ridges at Darkes Forest and Wedderburn on the eastern and western watersheds of the catchment, respectively. These rural settlements were established in the late nineteenth century.

Methods

Remote sensing

Aerial photographs flown in May–July 1982 (Wollongong 1:16 000 Colour, Misc. 1320) were interpreted to categorise variation in vegetation structure across the catchment. The following structural types were mapped onto a 1:25 000 scale topographic map base: forest (single-stemmed trees ≥ 5 m tall and ≥ 20% cover); woodland (single-stemmed trees ≥ 5 m tall and < 20% cover); mallee (multi-stemmed trees); heath (shrubs < 5 m tall).

Sampling strategy and data collection

Samples were stratified among categories of parent material, topography and vegetation structure (Table 1). Only eleven of 32 possible combinations of parent material, topography and structure were represented within the study area. Three of these sampling categories (forest on shale slopes, forest on sandstone plateau tops and heath on ironstone plateau tops) had very restricted occurrence and could only be allocated a small number of samples. The remaining eight categories were allocated at least four samples or more, depending on their geographic extent.

For all sampling categories except plateau alluvium dominated by shrubs, vegetation was sampled in 20 x 20 m quadrats, a standard size used by the National Parks and Wildlife Service and the National Herbarium in surveys of the coast and tablelands of New South Wales (e.g. Keith & Sanders 1990). All vascular plant species were allocated cover-abundance estimates on the Blaun-Blanquet scale (Poore 1955). Height and projective foliage cover were estimated for tall tree, small tree, shrub and ground-cover strata whenever present. Aspect, slope, parent material type and exposed rock (% cover) were recorded and scores were estimated for soil texture (clay/clay–loam/loam/sandy–loam/sand), drainage (waterlogged/damp/moist/dry) and depth (skeletal/shallow/deep). Disturbance history was recorded if evident. Soil samples

Table 1. Stratification of 56 quadrats among parent material (Shale, Sandstone, Ironstone, Alluvium), topography (Sl - slopes and gullies, Pl - plateau) and vegetation structure (of dominant stratum).

– indicates combinations of parent material, topography and structure that do not exist within the study area.

* indicates 60 transect samples as described in Keith & Myerscough (1993).

Parent Material:	Shale		Sandstone		Ironstone		Alluvium	
Topography:	Sl	Pl	Sl	Pl	Sl	Pl	Sl	Pl
Structure:								
forest	1	2,3, 4,5, 6,7, 8	18,23, 24,25, 26,27, 28,29, 30,31, 32,33, 34,35, 36	9,10, 11	–	–	–	–
woodland	–	–	–	37,38, 39,40, 41,42, 43	–	12,13, 14,15, 44,45, 46	–	–
mallee	–	–	–	47,48, 49,50, 51,52	–	–	–	–
heath	–	–	–	53,54, 55,56	–	16,17 21,22	19,20,	*

were collected for chemical analysis from selected sites. Soils were analysed for exchangeable cations, pH and electrical conductivity (methods in Keith 1991).

Plateau alluvium (upland swamps) supported a fine-scale mosaic of wet heath that varied greatly in floristics, structure and soil characteristics over short distances. This variation could not be sampled satisfactorily by 20 x 20 m quadrats and was the subject of a related study (Keith & Myerscough 1993), in which 60 belt transects were stratified by categories of soil moisture and shrub dominance. Each transect consisted of sixty 0.5 m x 0.5 m quadrats, in which the presence of each vascular plant species was scored and summed over the whole transect. Structural and environmental data were gathered in a manner similar to the other sampling categories. Data were archived in a data base and geographic information system held by the NSW National Parks and Wildlife Service.

Data analysis

Matrices of dissimilarity between samples were calculated using the Kulzcynski and Bray-Curtis association measures. These measures are 'non-linear' — species are weighted more highly in the calculation of similarity between two sites when they have higher abundances — and robust to variations in the response curves of species to environmental gradients (Faith et al. 1987). Each measure was applied both to raw data and data standardised by adjusting species to equal maxima, giving a total of four association matrices.

Cluster analysis was carried out using an unweighted pair-group arithmetic averaging procedure (UPGMA) with ß=-0.1 to achieve space conserving behaviour (i.e. relationships between groups stay the same as clustering proceeds, Lance & Williams 1967). Belbin & McDonald (1993) found this strategy was more likely to retrieve natural clusters than two-way indicator species analysis (TWINSPAN, Hill 1978). Classifications based on the four association matrices were compared using homogeneity analysis (Bedward et al. 1992). The classification with the most homogeneous groups was interpreted by attempting to match floristic groups with the sampling categories in Table 1.

Floristic groups were mapped using their correspondence with the sampling categories which were based on mappable features of parent material, topography and vegetation structure. Additional aerial photograph interpretation and field reconnaissance were undertaken to refine vegetation boundaries, particularly on plateau alluvium. Map boundaries were digitised and exported as a postscript file from the geographic information system into desktop publishing software (Aldus Pagemaker) for preparation of the layout and legend. The map was printed directly from this system without manual cartographic preparation.

Relationships between floristic composition and environmental variables were examined using global non-metric multidimensional scaling (NMDS), a method that is more robust to variations in species response to environmental gradients than alternative ordination techniques (Minchin 1987). NMDS maximises the rank-order agreement between values in the association matrix and inter-point distances in ordination space of a specified number of dimensions. Ordinations were fitted from 10 random starting configurations in each of 2, 3 and 4 dimensions. For each number of dimensions, the solution with the lowest stress (i.e. best rank order agreement with the association matrix) was selected for analysis of environmental and structural data.

Nine environmental variables (slope, aspect, elevation, distance from coast, parent material, soil texture, soil moisture, soil depth and rock cover) and six structural variables (height and cover for each of tree, shrub and ground strata) were standardised to a range of 0–1. The four categories of parent material were arranged in a sequence that reflected their relative nutrient status as indicated by the soil analyses (shale-alluvium-ironstone-sandstone). Aspect was coded as an index that reflected a sequence of increasing exposure (1: 120–210°; 2: 30–120° and 210–300°; 3: 0–30° and 300–360°). A vector for each variable was fitted to each of the three ordinations. Correlations between the vectors (indicating floristic composition) and their respective environmental and structural variables were tested using a Monte Carlo procedure (Minchin 1991).

The regional conservation significance of the vegetation was evaluated by: compiling a list of rare, threatened or biogeographically significant plant species; comparing levels of species richness with that in other areas; and attempting a comparison with vegetation elsewhere on Sydney sandstone using data from previous surveys and Pidgeon's (1941) regional classification.

Results

Native and introduced flora

Five hundred and ten vascular plant taxa were recorded in the O'Hares Creek catchment (list on reverse side of map). Of these, 382 were recorded in the 20 x 20 m quadrats, 165 were recorded in the swamp transects and 452 were recorded in either. Major plant families include Fabaceae (55 taxa), Myrtaceae (53), Proteaceae (44) and Cyperaceae (39).

A number of informal taxa were recognised where morphotypes or ecotypes could be distinguished repeatably in the field. These include two forms of *Hakea dactyloides* (one lignotuberous with broad leaves and large fruits, the other single-stemmed with narrower leaves and smaller fruits, Hovenden 1989), two forms of *H. teretifolia* (one multi-stemmed up to 1.5 m tall, the other single-stemmed up to 5 m tall), two forms of *Lepidosperma viscidum* (one with colourless resin and narrow biconvex leaves, the other with red resin and broader flat leaves), two forms of *Leptospermum trinervium* (one with broad leaves, the other with narrower leaves, Krauss 1994), two forms of *Pultenaea elliptica* (one with red flowers and a short growth form, the other with yellow flowers and a tall growth form) and two forms of *Xanthosia pilosa* (one with densely hairy entire dentate leaves, the other with sparsely hairy narrow lobed leaves).

Seventeen taxa are listed as rare or threatened in Australia (Briggs & Leigh 1988, Table 2), some of which have distributions that are essentially restricted to the Nepean ramp. An additional 17 taxa are uncommon either generally or in the Sydney region, three taxa are represented by atypically coastal populations, including one with a population disjunct from other occurrences of the species. Eleven taxa reach the southern limit of their known distribution in the O'Hares Creek catchment.

Fifty non-indigenous taxa, mainly in the families Asteraceae, Fabaceae and Poaceae, were recorded within the study area (reverse side of map). Sixteen of these are native to Australia, but were considered unlikely to be indigenous to part or all of the study area. Introduced taxa were largely confined to disturbed areas, including abandoned quarries, the interface between farmland and bushland, and along major roads and tracks. Weeds were most abundant at sites exposed to heavy vehicular traffic (e.g. along Bulli–Appin Road, North Cliff mine access road, Lysaghts Road) and/or nutrient-enriched runoff from developed sites such as farmland, mine sites and major

Table 2. Vascular plant taxa of conservation significance in the O'Hares Creek catchment

Significance codes in upper case follow Briggs & Leigh (1988): 2- geographic range < 100 km; 3- geographic range >100 km; V- vulnerable; R -rare; K- poorly known but may be rare or threatened; C- represented within a conservation reserve (a- >1000 plants, i- < 1000 plants, -unknown number). Significance codes in lower case: cl- coastal locality of typically inland taxon; dp- disjunct population; sl- southern limit of distribution; uc- uncommon; ucs- uncommon in Sydney region. Refer to Appendix 1 for explanation of community abbreviations.

Taxon	Significance	Community/Distribution
Acacia bynoeana	3VC-	SW & RH south of Wedderburn. Northern Sydney-Berrima.
Acacia stricta	ucs	SF near Darkes Forest. Coast & tablelands Qld–Tas.
Allocasuarina nana	cl	MH north of O'Hares Ck. Mainly tablelands Blue Mtns-East Gippsland.
Allocasuarina paludosa	ucs	RH scattered in eastern part of catchment. Northern Sydney–Tas.
Angophora hispida	sl	IH & MH in centre of catchment. Gosford–O'Hares Ck.
Banksia cunninghamii	cl	EGF scattered along O'Hares Ck gully. Scattered mainly along NSW tablelands and coastal East Gippsland.
Blandfordia cunninghamii	3RC-	WGF along Pheasant Ck, Wedderburn. Blue Mtns & Nepean ramp.
Blechnum ambiguum	uc	EGF restricted to sandstone overhangs throughout gullies. Mainly Sydney sandstone, also Qld.
Boronia serrulata	uc,sl	SW near Northcliff mine. Wondabyne–Manly & Loftus–O'Hares. Uncommon south of Sydney.
Callitris endlicheri	cl,dp	RPH south of Darkes Forest. Widespread in dry and semi-arid woodlands on the tablelands, western slopes and plains.
Corybas fordhamii	ucs	CH, SL & RH scattered in eastern part of catchment. Scattered on coast and tablelands.
Darwinia diminuta	3RCi,sl	MH near Northcliff mine. Manly-Ingleside & Loftus-O'Hares Ck.
Darwinia grandiflora	2RC-	WH & RH scattered in eastern part of catchment. Endemic to Nepean ramp.
Doryanthes excelsa	sl	SF & EGF throughout eastern part of catchment. Scattered localities from far north coast to Bulli-Appin Rd.
Epacris coriacea	3RC-	EGF near confluence of O'Hares & Cobbong Cks. O'Hares Ck–Macquarie Pass & Rhylstone.
Eriachne glabrata	sl	RH scattered in eastern part of catchment. Along coast Qld-O'Hares Ck.
Eucalyptus apiculata	2R	RH, MH & RPH in eastern part of catchment. Berrima, Nepean ramp & Linden. Intergrades with E. stricta.
Eucalyptus ligustrina	uc	SW west of Darkes Forest. Nepean ramp, Blue Mtns & Gibraltar Range.

Eucalyptus luehmanniana	2RCa,sl	MH scattered in eastern part of catchment. Gosford-O'Hares Ck.
Eucalyptus multicaulis	uc	SW & WGF mainly near Wedderburn. Hornsby Plateau, Nepean ramp, Blue Mtns, Jervis Bay & Budawang Range.
Eucalyptus squamosa	uc	WGF near Wedderburn. Hornsby Plateau & Nepean ramp.
Gonocarpus salsoloides	3RCa,sl	CH & SL scattered in eastern part of catchment. Port Macquarie–O'Hares Ck.
Grevillea diffusa var. *diffusa*	uc	SW & EGF throughout catchment. Menai–Cordeaux Dam. Form restricted to Bulli–Appin.
Grevillea longifolia	2RC-	EGF along O'Hares & Stokes Cks. Waterfall–Cataract Dam & Lawson–Springwood.
Hibbertia nitida	2RC-	EGF along O'Hares & Stokes Cks. Thornleigh–Manly & Oatley–Nepean Dam.
Leucopogon amplexicaulis	uc	EGF along O'Hares & Stokes Cks. Gosford–Pigeon House Mtn.
Leucopogon exolasius	2VC-,sl	EGF scattered along O'Hares & Stokes Cks. Woronora–Georges Rivers & Grose River.
Lomandra fluviatilis	3RC-	RS along O'Hares & Stokes Cks. Colo River–Cataract Dam.
Melaleuca deanei	3RC-	SW at Wedderburn. Hornsby Plateau & Nepean ramp.
Melaleuca squamea	ucs	CH scattered in eastern part of catchment. Scattered along tablelands & coast northern NSW-Tasmania.
Melichrus urceolatus	ucs	SW in western part of catchment. Widespread on coast, tablelands, slopes & plains of NSW, Qld & Vic, but only 2 localities in Sydney region.
Monotoca ledifolia	3RC-	RPH scattered in south-eastern part of catchment. Blue Mtns & Nepean ramp.
Persoonia mollis subsp. *nectans*	uc	EGF east of Darkes Forest. Restricted to Nepean ramp.
Prasophyllum nublingii	2KC-,sl	SW in southern part of catchment. Royal NP–O'Hares Ck.
Pseudanthus orientalis	ucs,sl	BT & MH scattered in eastern part of catchment. Qld–O'Hares Ck, usually on coastal sand dunes.
Pultenaea aristata	2VC-	BT, RH & MH mainly in eastern part of catchment. Helensburgh–Mt Kiera & Budawang Range.
Pultenaea divaricata	ucs	TT & CH scattered in larger swamps. Blue Mtns–Corang.
Pultenaea hispidula	ucs	SF scattered in eastern part of catchment. Hornsby Plateau–East Gippsland.
Tetratheca neglecta	3RC-	SW, IW & MH throughout catchment. Sutherland–Robertson.
Tetratheca shiressii	sl	SW near Northcliff mine. Watagan Mtns–Hawkesbury River & Sutherland–O'Hares Ck
Thelymitra circumsepta	ucs	RH & IW in eastern part of catchment. Northern NSW coast–East Gippsland.

roads. The most abundant introduced species along roads was *Andropogon virginicus*. Localised infestations of *Ageratina adenophora* occur south of Darkes Forest coal mine, where treated sewerage effluent was sprayed upon native vegetation. Native vegetation away from developed sites is remarkably free of weeds. Only three out of the 56 samples included introduced taxa. The three taxa recorded (*Hypochoeris radicata*, *Conyza albida* and *Rubus ?discolor*) had cover-abundance scores of 1 (uncommon and < 5% cover). Watercourses were apparently free of weeds, with no introduced taxa recorded in any of the riparian samples.

Classification and mapping

Classifications based on raw data grouped samples into more homogeneous groups than those based on standardised data (Figure 2). The two classifications based on raw data were similar, but the Kulzcynski classification (Figure 3) corresponded more closely with the sampling categories (Table 1) than the Bray-Curtis classification.

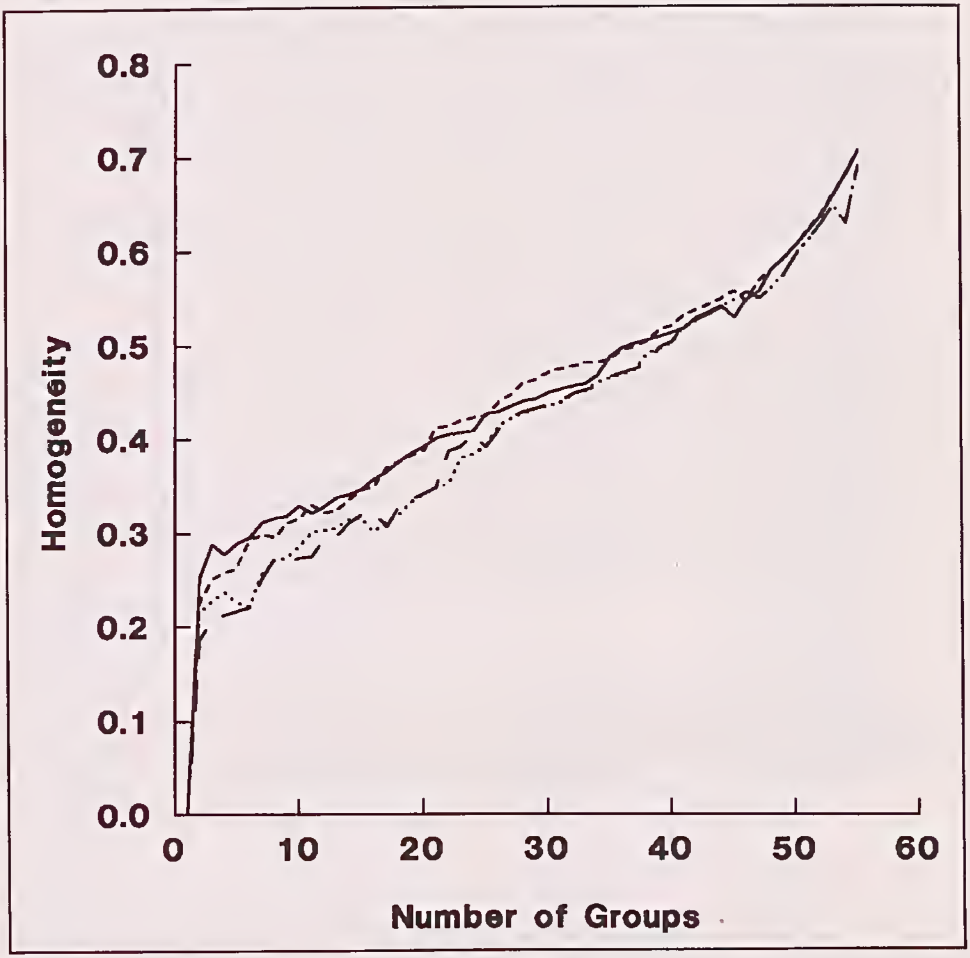

Figure 2. Homogeneity curves for site classifications based on raw data and Kulzcynski coefficient (-----), raw data and Bray-Curtis coefficient (——), standardised Kulzcynski coefficient (·-·) and standardised Bray-Curtis coefficient (- - -).

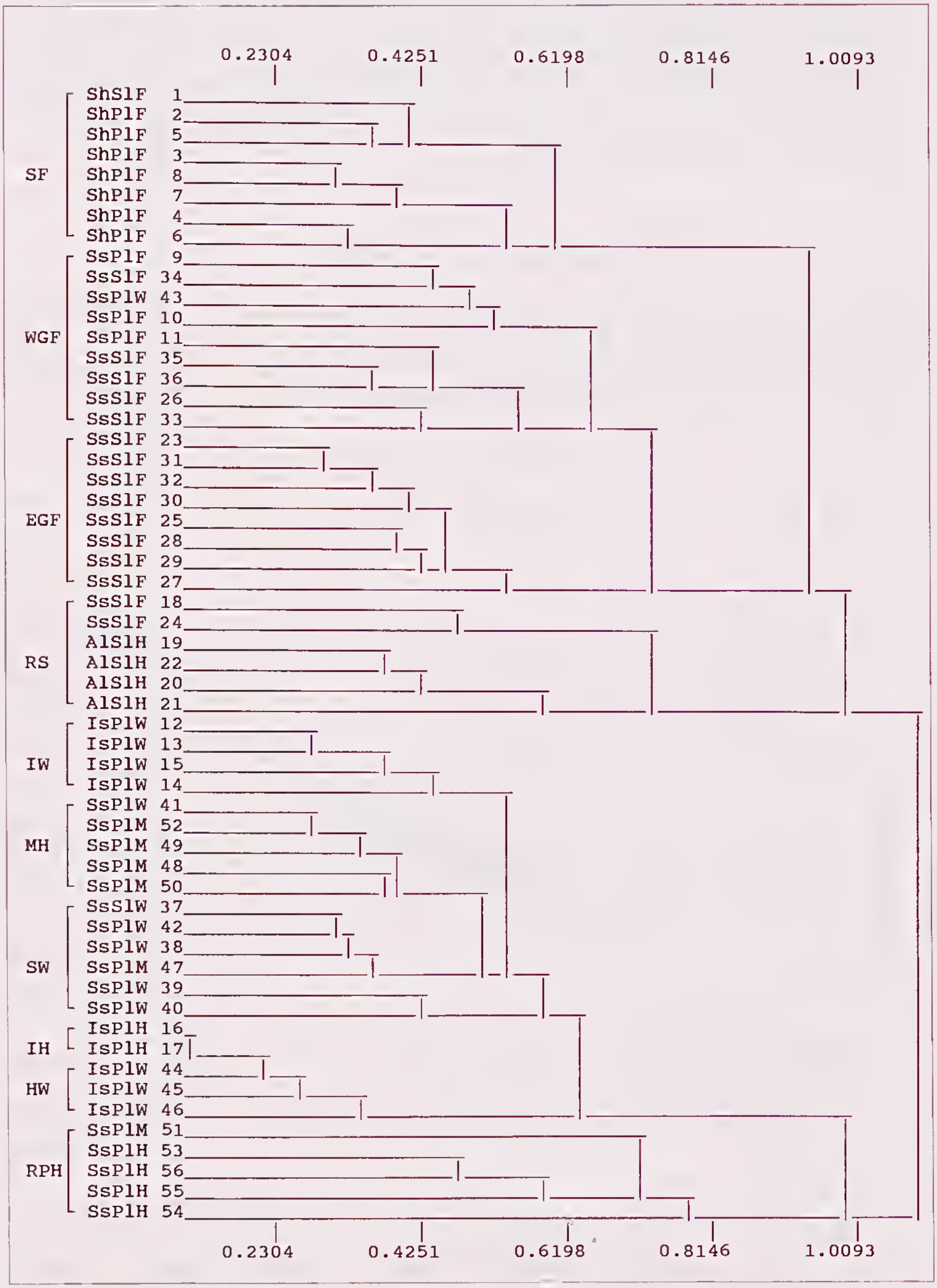

Figure 3. Classification of non-swamp sites based on raw data and Kulzcynski coefficient with UPGMA clustering. See Appendix 1 or vegetation map for abbreviations of plant community names. Sample labels indicate sampling cell to which sample belongs (Table 1): Sh – shale; Ss – sandstone; Is – ironstone; Al – creek alluvium; Pl – plateau top; Sl – slopes and gullies; F – forest; W – woodland; M – mallee; H – heath.

Five major groups can be identified from Figure 2 and correspond to groups of sampling categories defined in Table 1: forest on shale (eight sites); forest on sandstone gully slopes (17 sites); scrub on alluvium in gullies (six sites); woodland, mallee and heath on the sandstone/ironstone plateau (20 sites); and heath on the sandstone plateau (five sites).

The first major group was made up of seven forested shale sites on the plateau and one on gully slopes and was recognised as a single community, 'Shale Forest'. The second major group included 13 forested sites on sandstone gully slopes and four on the plateau. It was split into two communities (Figure 3): one confined to the western side of the catchment, 'Western Gully Forest'; the other confined to the eastern side of the catchment, 'Eastern Gully Forest'. The third major group included four heath sites on alluvium in gullies and two forested sites in sandstone gullies and was recognised as a single community, 'Riparian Scrub'.

The fourth major group was a complex of sites from five different sampling categories (Figure 3). Within this complex, three woodland groups could be distinguished from one another on floristic grounds: 'Ironstone Woodland' (sites 12, 13, 14, 15); 'Sandstone Woodland' (sites 37, 42, 38, 47, 39, 40); and 'Heath Woodland' (sites 44, 45, 46). Map boundaries were determined by field traverse because their structure and parent materials were difficult to separate on aerial photographs. A group of mallee sites (41, 52, 49, 48, 50) was closely related in floristics to Sandstone Woodland, but was distinct in structural characteristics and mapped as 'Mallee Heath'.

Table 3. Correlations of environmental and structural variables with floristic ordination vectors in 2, 3 and 4 dimensions

	Number of Ordination Dimensions		
	4	**3**	**2**
Slope	0.6528***	0.5367***	0.3576*
Aspect Index	0.3482ns	0.2204ns	0.1737ns
Elevation	0.6811***	0.6756***	0.3524*
Distance from Coast	0.7169***	0.7056***	0.0439ns
Parent Material	0.8329***	0.6602***	0.5888***
Soil Depth	0.8343***	0.8365***	0.7890***
Soil Quartz	0.7274***	0.6937***	0.6292***
Soil Moisture	0.8108***	0.7422***	0.6516***
Rock cover	0.7222***	0.7208***	0.6763***
Tree height	0.8888***	0.8296***	0.7757***
Tree cover	0.8173***	0.8100***	0.7913***
Shrub height	0.7473***	0.7401***	0.7087***
Shrub cover	0.4474*	0.4422*	0.3901*
Ground height	0.5432***	0.5257***	0.4377***
Ground cover	0.7252***	0.6455***	0.4364***

*** = significant at $P < 0.001$
* = significant at $P < 0.05$
ns = not significant $P > 0.05$

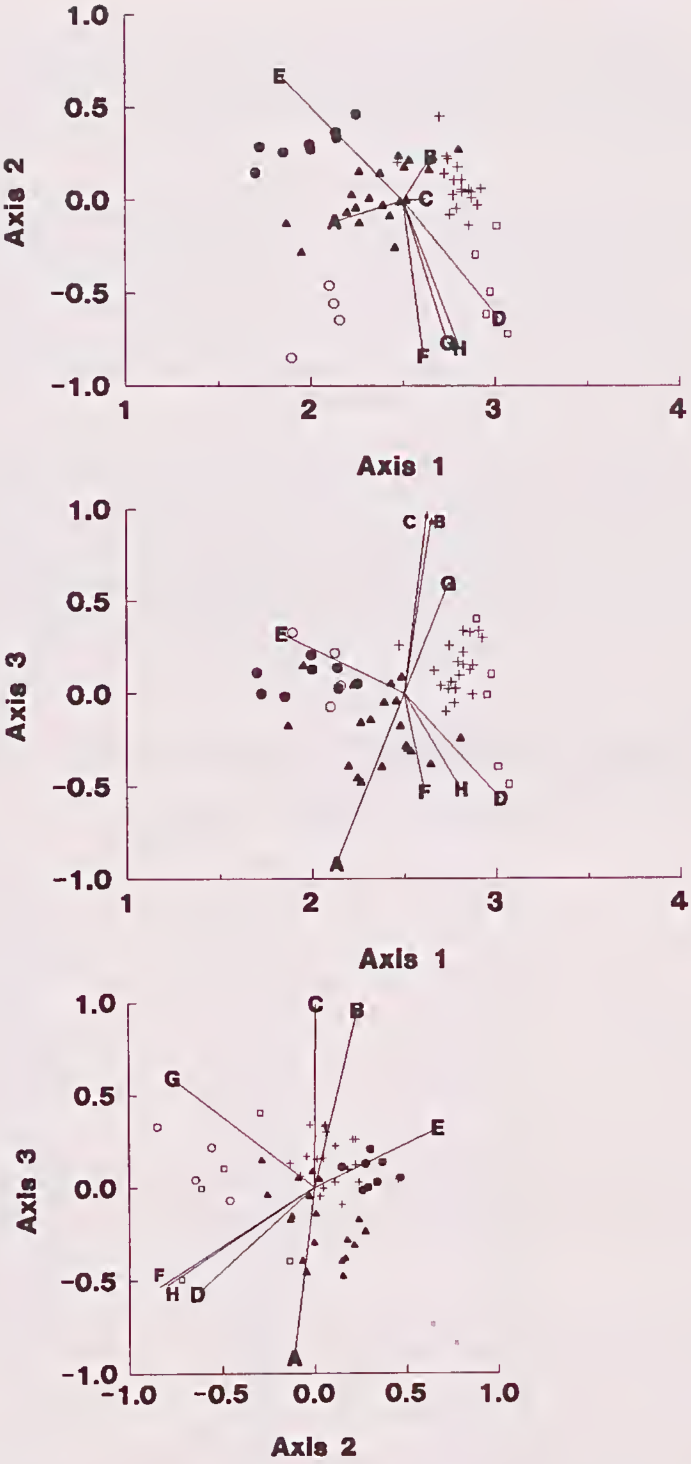

Figure 4. Three-dimensional ordination of non-swamp sites showing vectors significantly correlated with environmental variables: A – slope; B – elevation; C – distance from coast; D – parent material; E – soil depth; F – soil quartz; G – soil moisture; H – rock cover. Symbols show groups of plant communities: - SF; - - EGF and WGF; o - RS; [] - RPH; + - all other communities.

Two heath sites on ironstone (16, 17) had similar floristic composition to the Heath Woodland sites (44, 45, 46) but, primarily because of their different structure, were mapped separately as 'Ironstone Heath'. The fifth major group in Figure 2 was recognised as a single community, 'Rock Pavement Heath'.

Classification of upland swamp (heath on plateau alluvium) communities was based on the analysis by Keith & Myerscough (1993) which recognised five communities: Ti-Tree Thicket; Cyperoid Heath; Sedgeland; Restioid Heath; and Banksia Thicket. However, only two of these could be mapped separately using aerial photopattern (Ti-tree Thicket and Banksia Thicket), so the remaining three were included in a single map unit, 'Sedgeland–Heath Complex'.

The vegetation map shows the distribution of plant communities described in Appendixes 1 and 2.

Environmental and structural relationships with floristic composition and richness

The 4-dimensional ordination had a lower level of stress (0.0777), than ordinations in three (0.0992) and two (0.1587) dimensions. Vectors fitted to the 4-dimensional ordination were more highly correlated with environmental and structural variables than those fitted in three and two dimensions, the latter giving a poor representation of floristic relationships, particularly with slope and elevation (Table 3). However, the 3-dimensional ordination (Figure 3) represented all significant relationships in fewest dimensions.

Slope, elevation, distance from coast, parent material, soil depth, quartz and moisture, rock cover, tree height and cover, shrub height, ground stratum height and cover were all highly correlated with floristic composition, as indicated by the 3- and 4-dimensional ordinations ($P < 0.001$, Table 3). Shrub cover was marginally correlated with floristic composition ($P < 0.05$). There was no correlation between floristics and aspect ($P > 0.05$). Soil depth, soil quartz, rock cover and parent material were closely related ($P < 0.001$, Figure 4). Height and tree cover were highly correlated with one another and with soil moisture ($P < 0.001$). There were also significant correlations between the tree stratum and soil depth, slope and shrub cover (Figure 4). Elevation and distance from the coast were inversely correlated ($P < 0.001$), but independent of other variables. Aspect was not correlated with any of the other environmental or structural variables ($P > 0.05$, Figure 4).

Plant communities showed high fidelity with one type of parent material, and there were corresponding differences between communities in soil properties (Table 4). The five swamp communities occupied soils that were deep, fine-textured, waterlogged and without exposed rock. Shale Forest also occupied deep fine-textured soils, but these were well drained and their fine texture was due to a high proportion of mineral clay and silt, rather than fine organic particles as was the case in swamp soils. Rock Pavement Heath was distinguished from remaining communities by its skeletal soils and extensive outcrops of rock. Communities on sandstone had the highest levels of soil quartz and exposed rock. Forest and woodland communities occupied well-drained soils, while heath and swamp communities occurred on soils whose drainage is impeded to varying degrees. Soils supporting Ironstone Woodland, Sandstone Woodland, Mallee Heath, Ti-tree Thicket and Shale Forest had higher pH than other communities. Shale Forest, Eastern Gully Forest, Ironstone Woodland, Sandstone Woodland and Mallee Heath form a sequence of decreasing soil fertility, as indicated by conductivity and exchangeable cations (Table 4). Among

Table 4. Soil characteristics of plant communities

Data for soil depth, quartz and moisture are medians with ranges in parentheses for scales of 1–5, 1–4 and 1–3, respectively. All other data are means with standard errors in parentheses. Parent materials: Sh– shale; Ss– sandstone; Al– creek alluvium; Is ironstone; Sw– swamp alluvium. Rock cover in %, electrical conductivity in mS.cm^{-1}, exchangeable cations in milliequivalents/100g air-dried soil.

Community Cat.	Parent Material	Soil Depth	Soil Quartz	Soil Moisture	Rock Cover	pH	Elec. Cond.	Exch. Na	Exch. K	Exch. Ca	Exch. Mg	Exch. Al	Total Ex.
Shale Forest	Sh	5	1	1	1	4.3	0.062	0.16	0.23	2.12	1.39	1.72	5.62
		(3–5)	(1–3)	(1–2)	(1)	(0.3)	(0.012)	(0.05)	(0.10)	(1.29)	(0.39)	(0.65)	(2.28)
Western Gully Forest	Ss	3	3	1	5	–	–	–	–	–	–	–	–
		(2–4)	(2–4)	(1–1)	(2)								
Eastern Gully Forest	Ss	3	4	1	11	3.6	0.050	0.07	0.14	0.80	0.88	0.81	2.70
		(3–3)	(3–4)	(1–2)	(2)	(0.1)	(0.006)	(0.02)	(0.02)	(0.03)	(0.36)	(0.15)	(0.56)
Riparian Scrub	Al	3	4	3	11	–	–	–	–	–	–	–	–
		(3–4)	(3–4)	(1–3)	(2)								
Ironstone Woodland	Is	3	2	1	1	4.5	0.038	0.06	0.05	0.52	0.36	0.72	1.70
		(3–3)	(2–3)	(1–2)	(1)	(0.1)	(0.003)	(0.01)	(0)	(0.11)	(0.14)	(0.22)	(0.48)
Sandstone Woodland	Ss	3	3	1	3	4.4	0.027	0.05	0.06	0.32	0.28	0.28	0.99
		(3–3)	(2–4)	(1–2)	(2)	(0.1)	(0.002)	(0.01)	(0.01)	(0.08)	(0.07)	(0.11)	(0.16)

Ironstone Heath	Is	3	1	3	0	–	–	–	–	–	–	–	–
		(3–3)	(1–1)	(3–3)	(0)								
Heath Woodland	Is	3	2	2	0	–	–	–	–	–	–	–	–
		(3–3)	(2–2)	(1–3)	(0)								
Rock Pavement Heath	Ss	1	4	2	60	–	–	–	–	–	–	–	–
		(1–1)	(4–4)	(2–3)	(9)								
Banksia Thicket	Sw/Ss	4	2	3	0	3.8	0.059	0.08	0.04	0.13	0.28	1.75	2.30
		(3–4)	(2–3)	(3–3)	(0)	(0.1)	(0.007)	(0.01)	(0.01)	(0.05)	(0.04)	(0.40)	(0.45)
Restioid Heath	Sw	4	2	3	0	3.9	0.043	0.05	0.03	<0.05	0.11	0.67	0.83
		(3–4)	(1–3)	(3–3)	(0)	(0.1)	(0.004)	(0.01)	(0.01)	(–)	(0.04)	(0.18)	(0.24)
Sedgeland	Sw	4	1	3	0	4.1	0.049	0.05	0.04	<0.05	0.12	0.68	0.85
		(3–4)	(1–3)	(3–4)	(0)	(0.1)	(0.003)	(0.01)	(0.01)	(–)	(0.02)	(0.12)	(0.15)
Cyperoid Heath	Sw	5	1	4	0	3.8	0.080	0.12	0.08	0.08	0.30	2.33	2.86
		(4–5)	(1–3)	(3–4)	(0)	(0.1)	(0.012)	(0.02)	(0.01)	(0.03)	(0.04)	(0.45)	(0.54)
Ti–tree Thicket	Sw	5	1	4	0	4.4	0.164	0.53	0.20	1.31	0.97	2.80	4.94
		(5–5)	(1–2)	(4–4)	(0)	(0.2)	(0.013)	(0.20)	(0.03)	(0.74)	(0.41)	(0.57	(1.00)

the swamp communities, Ti-tree Thicket had the most fertile soils, Restioid Heath and Sedgeland the least fertile and Cyperoid Heath and Banksia Thicket were intermediate. Swamp soils had higher levels of Aluminium as a proportion of total exchangeable cations than soils supporting forest and woodland vegetation. Swamp soils had similar levels of total exchangeable cations and greater conductivity than those of forests and woodlands when considered on a dry-weight basis. However, if data in Table 4 could be corrected for variations in bulk density due to organic matter, overall fertility of swamp soils would be low to moderate, relative to soils supporting forests and woodlands.

Trees were tallest in Shale Forest and Eastern and Western Gully Forests, but had more cover in Shale Forest than the other two forest communities (Figure 6a). Mallee Heath had the shortest trees, but these were greater in cover than those of the three woodland communities. Trees were generally absent from Riparian Scrub, Ironstone Heath, Rock Pavement Heath and the five swamp communities. Shrubs were tallest and had least cover in Shale Forest and were tall with most cover in Banksia Thicket. The remaining communities had similar shrub strata, except that shrubs were taller in Riparian Scrub, Ti-tree Thicket and Eastern and Western Gully Forests (Figure 6b).

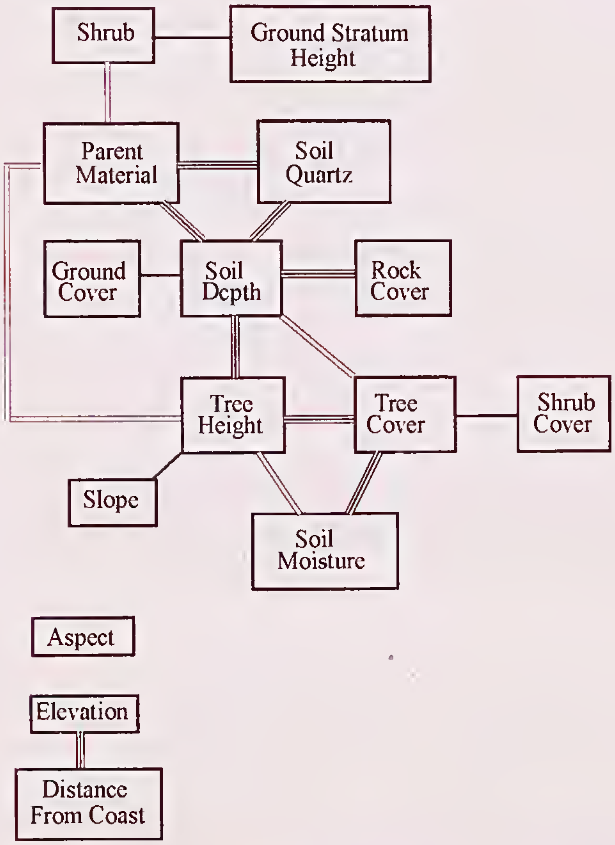

Figure 5. Correlations among environmental variables and structural characteristics of vegetation. Triple line $P < 0.001$; double line $P < 0.01$; single line $P < 0.05$.

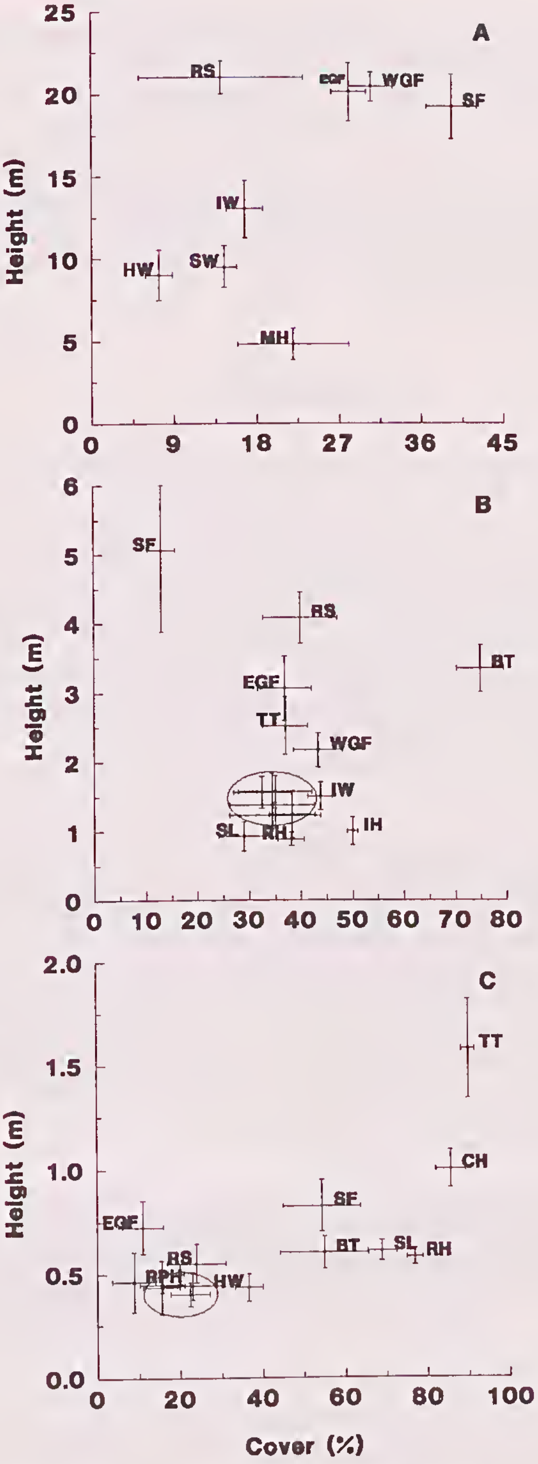

Figure 6. Mean height and cover of (a) tree strata, (b) shrub strata and (c) ground strata for each plant community. Refer to Appendix 1 or vegetation map for abbreviations of plant community names. Errors bars are standard errors of the mean. In (b) the ellipse contains unlabelled data points for SW, HW, MH, RPH & CH. In (c) the ellipse contains unlabelled data points for WGF, IW, SW, MH & IH.

The five swamp communities had a dense and tall groundcover, as did Shale Forest, though its composition was very different. The groundcover of Heath Woodland and Ironstone Heath was similar in composition to the swamp communities, though less dense. Rock Pavement Heath had the least ground cover (Figure 6c).

The most species-rich communities were Mallee Heath, Ironstone Heath and Heath Woodland (Table 5). Restioid Heath is similarly species rich, but caution is required when comparing richness between swamp and non-swamp communities because of the different scales at which they were recorded. Species Richness was lowest in Rock Pavement Heath and Ti-tree Thicket.

Discussion

Vegetation patterns and environmental relations

The major dichotomy in the dendrogram (Figure 3) distinguishes plant communities on shale, creek alluvium and sandstone gullies from those on sandstone and ironstone sites on the plateau. Upland swamps comprise a third major group of communities. The first group of communities is characterised by relatively fertile, well-drained soils, the second group occurs on soils of low fertility and free to moderate drainage, while the third group is restricted to waterlogged soils of varying fertility. Differences in soil chemistry, texture and moisture also delimit individual communities within these groups (Table 4). A suite of inter-related soil factors are highly correlated with overall trends in floristic composition (Table 3) and with aspects of vegetation structure (Figure 5).

The identification of soil fertility and moisture as determinants of plant community distribution is consistent with findings of earlier workers. Beadle (1954, 1962) and Clements (1983) demonstrated the role of soil nutrients, particularly phosphorus, in delimiting forest and woodland communities on Sydney shales and sandstones. Pidgeon (1938), Davis (1941) and Buchanan (1980) identified soil moisture as a factor influencing structure and composition, especially on sandstone. In the Darkes Forest–Maddens Plains–Sublime Point area, Davis (1941) demonstrated differences in the water-retaining capacity and organic content of soils between a *Eucalyptus piperita* association (cf. Shale Forest), an *E. sieberi* association (cf. Sandstone Woodland, Ironstone Woodland and Heath Woodland) and a *Gymnoschoenus sphaerocephalus* association (cf. Cyperoid Heath and Restioid Heath).

Within O'Hares Creek catchment, vegetation patterns attributable to variation in soil moisture may be thought of at local and regional scales. At a local level, the response of floristics and structure to changes in drainage due to parent material and landform over short distances is illustrated by the large number of map units present in a small area, particularly in the eastern part of the catchment where there are fine-scale mosaics including three woodland communities, three heath communities and five upland swamp communities. The rainfall gradient superimposes a regional trend on moisture availability due to the occurrence of certain plant communities and species. Such a trend is illustrated, for example, by the diminishing extent of upland swamps, the replacement of Eastern Gully Forest with Western Gully Forest and the correlation of overall floristic composition with decreasing elevation and increasing distance from the coast (Table 3). Burrough et al. (1977) identified similar regional trends in vegetation in relation to a rainfall gradient across the Budderoo Plateau, 50 km south of Darkes Forest.

Table 5. Species richness of plant communities

Community		mean	se	n	area (m^2)
O'Hares Creek catchment					
Shale Forest		41	2	8	400
Western Gully Forest		40	1	9	400
Eastern Gully Forest		57	4	8	400
Riparian Scrub		36	6	6	400
Ironstone Woodland		52	2	4	400
Sandstone Woodland		57	2	6	400
Mallee Heath		64	4	5	400
Ironstone Heath		62	0	2	400
Open Ironstone Woodland		66	3	3	400
Rock Pavement Heath		23	6	5	400
Banksia Thicket		40	2	7	15
Restioid Heath		55	2	15	15
Sedgeland		40	3	13	15
Cyperoid Heath		37	2	16	15
Ti-tree Thicket		24	2	9	15
Yengo National Park[1]					
Dry forest	(1)	44		11	400
	(2)	47		6	400
	(3)	45		15	400
Dry woodland	(4)	37		43	400
Garrigal National Park[2]					
Dry forest	(7)	42		2	400
Dry forest/woodland	(10)	49		3	400
	(12)	55		6	400
Dry woodland	(13)	55		8	400
Yuraygir National Park[3]					
Wet/dry forest	(5)	52	8	3	400
Dry forest	(6)	30	2	10	400
	(7)	40	2	3	400
	(17)	42	3	3	400
Dry heath	(35)	38	2	11	400
Wet heath	(37)	30	1	11	400
	(39)	26	2	18	400
South East Forests[4]					
Wet forest	(9l)	39	2		400
Dry forest	(16)	39	2		400
	(26l)	30	2	17	400
	(28)	33	3	11	400
Dry heath	(33)	35	4	6	400
Upland swamp	(40)	35	4	5	400

Sources: 1. Sanders et al. (1988); 2. Sherringham & Sanders (1993); 3. Griffith (1988); 4. Keith & Sanders (1990). Numbers in parentheses are community numbers used by respective authors.

Conservation

Representativeness of plant communities and species

O'Hares Creek catchment samples a small part of the extensive Sydney sandstone landscape. Sandstone Woodland and Eastern Gully Forest, collectively covering 64% of the catchment, typify a recurring pattern of woodland on ridges and forest in gullies that is widespread throughout the Sydney sandstone landscape (Pidgeon 1938). While a large proportion of this landscape is represented within reserves, the diversity and regional variability of its vegetation may not be fully appreciated.

Keith & Myerscough (1993) have drawn attention to the species richness of upland swamps in O'Hares Creek catchment, which is high relative to other shrub-dominated vegetation types around the world. Levels of species richness in dry sclerophyll forests, dry sclerophyll woodlands and heathlands at O'Hares Creek are higher than in comparable plant communities in other parts of coastal New South Wales (Table 5), exceed those in wet sclerophyll forests on the north and south coast (e.g. Binns & Chapman 1992, Keith & Sanders 1990) and are high relative to those in temperate forests and woodlands on other continents (e.g. Peet 1978).

Pidgeon (1941) noted that many species are restricted in their distribution to parts of the sandstone area, while others occur throughout. She divided the Sydney sandstone into regions that differ from one another physiographically, climatically and in the groups of vegetation types they support. Most of O'Hares Creek catchment samples the Nepean Ramp sub-region, but in the west it includes a southern outlier of the Macdonald region. Of six existing conservation reserves on the Nepean Ramp, two (Illawarra and Macquarie Pass National Parks) are located on the Illawarra Escarpment and sample extremely small areas of the sandstone plateau, and four (Royal, Heathcote, Garrawarra and Georges River NPs) are located on the northern edge of the plateau. The southern outlier of the Macdonald region is not represented in any reserves. Unlike the combined reserves to the north, O'Hares Creek samples a transition from the Coastal region to the Macdonald region (Pidgeon 1941) that also occurs over a longer and interrupted stretch of country to the north of Sydney.

Data gathered since Pidgeon's (1941) work allow further insight into the heterogeneity of Sydney sandstone vegetation by comparing the occurrence of selected taxa in analogous communities of different regions. The taxa selected for comparison were trees and widespread genera of understorey shrubs (*Grevillea*, *Leucopogon*, *Acacia* and *Pultenaea*). Analogies between plant communities in different part of Sydney were determined by identifying vegetation in similar habitats (i.e. sandstone gullies and ridges capped by Hawkesbury shale). In forest communities in sandstone gullies only four of 42 species (10%) were represented in more than seven of ten localities surveyed, whereas 27 species (64%) were recorded at three or less of the ten localities (Table 6a). Representation of species is even more localised in widely scattered, but locally restricted vegetation types, in which floristic similarities between stands may be limited by dispersal. In forests on shale lenses only five of 30 species (17%) were represented at more than three of five localities surveyed, whereas 22 species (73%) were represented at less than three of the five localities (Table 6b). Moreover, each of the five 'shale forests' includes species not known from any of the others.

Full assessment of the conservation status of Sydney sandstone vegetation requires quantitative analysis of more comprehensive data than that currently available. Nonetheless, these data emphasise the importance of conserving samples of vegetation types throughout their range, if the full diversity and variability of Sydney sandstone vegetation is to be conserved.

Table 6. Representation of selected taxa in analogous vegetation types at various localities on Sydney sandstone (X-dominant, x-other taxa)

a) Forest in Sandstone Gullies. Regions after Pidgeon (1941): Cn- Coastal, Nepean Ramp sub-region; Ch- Coastal, Hornsby Plateau sub-region; Co- Coastal, Ourimbah sub-region; Mn- Macdonald north; Ms- Macdonald south; LBM- Lower Blue Mountains; UBM- Upper Blue Mountains. Localities: OHE- O'Hares Creek east (comm. EGF, this study); OHW -O'Hares Creek west (comm. WGF, this study); RNP- Royal NP (Keith unpubl. data); BBP- Bents Basin NP (comms. 8, 9 & 10, Benson et al. 1990); KAT- Katoomba area (comm. 9i, Keith & Benson 1988); YNP- Yengo NP (comms. 1, 2 & 3, Sanders et al. 1988); DNP- Dharug NP (comm. C1, Clarke & Benson 1986); GNP- Garrigal NP (map unit 9, Sherringham & Sanders 1993); KCP- Ku-ring-gai Chase NP (comm. 9, Thomas & Benson 1985); BWP- Brisbane Water NP (comm. 4, Benson & Fallding 1981).

Region:	**Cn**	**Ms**	**Cn**	**LBM**	**UBM**	**Mn**	**Mn**	**Ch**	**Ch**	**Co**	
Locality:	**OHE**	**OHW**	**RNP**	**BBP**	**KAT**	**YNP**	**DNP**	**GNP**	**KCP**	**BWP**	**Tot**
Trees											
Angophora bakeri						x					1
Angophora costata	X	X	X	X		X	X	X	X	X	9
Angophora floribunda						x				x	2
Eucalyptus agglomerata	x	X	x	x		x	x				6
Eucalyptus capitellata										x	1
Eucalyptus consideniana		x									1
Eucalyptus eugenioides				x							1
Eucalyptus eximia				x		x	x		x	x	5
Eucalyptus gummifera	x	X	x	X		x	x	X	x	X	9
Eucalyptus haemastoma									x	x	2
Eucalyptus multicaulis		x									1
Eucalyptus oblonga	x	x							x	x	4
Eucalyptus oreades				X							1
Eucalyptus pellita										x	1
Eucalyptus pilularis		x		X		X					3
Eucalyptus piperita	X	x	X		X	X	X	X	X	X	9
Eucalyptus punctata		X	x	x		x	x		x	x	7

Eucalyptus radiata					x						1
Eucalyptus scias								x			1
Eucalyptus sieberi	x		**X**		**X**			**X**	x	x	6
Eucalyptus umbra ssp. *umbra*									x	x	2
Syncarpia glomulifera						**X**	x			x	3
Shrubs											
Grevillea buxifolia		x	x			x	x	x	x	x	7
Grevillea diffusa	x	x	x								3
Grevillea linearifolia								x	x	x	3
Grevillea longifolia	x	x									2
Grevillea mucronulata	x	x	x	x	x		x				6
Grevillea oldei										x	1
Grevillea oleoides		x	x								2
Grevillea phylicoides							x				1
Grevillea sericea	x		x	x	x		x	x	x	x	8
Grevillea sphacelata		x	x								2
Leucopogon amplexicaulis	x		x					x	x	x	5
Leucopogon ericoides	x	x	x						x	x	5
Leucopogon esquamatus	x										1
Leucopogon exolasius	x	x									2
Leucopogon lanceolatus	x		x	x	x		x			x	6
Leucopogon margarodes										x	1
Leucopogon microphyllus		x	x					x			3
Leucopogon muticus				x	x	x	x				4
Leucopogon setiger			x					x		x	3
Leucopogon virgatus				x							1

b) Forest on Hawkesbury Shale caps. Regions after Pidgeon (1941): Cn- Coastal, Nepean Ramp sub-region; Ch- Coastal, Hornsby Plateau sub-region; Co- Coastal, Ourimbah sub-region. Localities: O'Hares Creek catchment (comm. SF, this study); RNP- Royal NP (Keith unpubl. data); GNP- Garrigal NP (map units 10 & 12, Sherringham & Sanders 1993); KCP- Ku-ring-gai Chase NP (comm. 8, Thomas & Benson 1985); BWP- Brisbane Water NP (comm. 4S, Benson & Fallding 1981).

Region:	**Cn**	**Cn**	**Ch**	**Ch**	**Co**	
Locality:	**OHC**	**RNP**	**GNP**	**KCP**	**BWP**	**Total**
Trees						
Angophora costata	X	x	X	X	X	5
Eucalyptus capitellata			X			1
Eucalyptus globoidea	X	X			x	3
Eucalyptus gummifera	X	x	X		X	4
Eucalyptus haemastoma					x	1
Eucalyptus oblonga					x	1
Eucalyptus paniculata		x				1
Eucalyptus pilularis		X		X		2
Eucalyptus piperita	X					1
Eucalyptus punctata				X		1
Eucalyptus resinifera		x		x		2
Eucalyptus saligna	x					1
Eucalyptus sieberi	x		X			2
Eucalyptus umbra ssp. *umbra*			X		x	2
Syncarpia glomulifera		x		x	x	3

Shrubs						
Acacia binervata	x					1
Acacia irrorata	x	x				2
Acacia linifolia	x	x		x	x	4
Acacia longifolia	x	x				2
Acacia longissima			x	x		2
Acacia myrtifolia	x	x	x		x	4
Acacia stricta	x					1
Acacia ulicifolia				x		1
Pultenaea daphnoides	x			x	x	3
Pultenaea elliptica					x	1
Pultenaea ferruginea var. *deanei*				x	1	
Pultenaea hispidula	x	x	x	x		4
Pultenaea linophylla	x					1
Pultenaea microphylla			x			1
Pultenaea rosmarinifolia					x	1

O'Hares Creek catchment contains plant communities that are not well sampled in existing conservation reserves on Sydney sandstone (Table 6, Appendix 1). These include the five upland swamp communities, Shale Forest, Western Gully Forest, Ironstone Woodland, Heath Woodland and Rock Pavement Heath. Sandstone Woodland and Eastern Gully Forest are comparatively well represented in reserves. Stands of Mallee Heath and Ironstone Heath are significant because these represent the southern distributional limits of these community types. Examples of Riparian Scrub in O'Hares Creek catchment are unaffected by weed invasion, unlike many comparable stands within reserves where runoff is polluted by urban and industrial development in upper catchments. Overall levels of disturbance are minimal and the introduced flora is small, though both are increasing in recent years mainly as a result of mining activities. Disturbed areas such as clay quarries and tracks regenerate over time with native species, though not necessarily to their original species composition. Exceptions with significant weed invasion include sites exposed to frequent vehicular use (e.g. Bulli–Appin Rd) and sites exposed to enriched moisture and/or nutrients (e.g. mine effluent irrigation sites, rural interfaces).

O'Hares Creek Catchment includes a large number (17) of nationally rare or threatened plant taxa (Table 2). For three of the most restricted taxa (*Pultenaea aristata, Leucopogon exolasius* and *Grevillea longifolia)* the area contains major populations, whose maintenance is important for overall conservation of these species. O'Hares Creek is also an important biogeographic location for eleven taxa that reach their southern limit of distribution in the area, including seven Sydney sandstone endemics and two species that extend well north of Sydney along coastal sands. The population of *Callitris endlicheri* is also of biogeographic significance. Its presence in an area that receives two to three times the average annual rainfall of typical *C. endlicheri* habitat, and its isolation from other populations of the species, suggest that it persists as a relic of populations that were more widespread during a drier late Pleistocene climate.

A large volume of biological and geomorphological data has been gathered in O'Hares Creek area since Allan Cunningham made his early collections. Completed studies address topics of stream dynamics and landscape evolution (Harden 1965), upland swamp geomorphology and palynology (Young 1983, 1986a,b), vegetation patterns and dynamics (Davis 1936, 1941, Keith 1991, Keith & Myerscough 1993), rare plant ecology (Andren et al. 1987, Auld et al. 1993) and koala ecology (Cork et al. 1988, Close 1993). Further studies in fire ecology, plant reproductive biology and ecological modelling are in progress. Universities of Sydney and Wollongong use the area for practical components of undergraduate courses on ecology and conservation biology. These studies and a geographic information system developed as part of the current work underpin the value of O'Hares Creek catchment as a scientific reference area and as an important augmentation to the regional network of conservation reserves.

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Appendix 1: Description of Plant Communities

SF Shale Forest (Figure 7)

Samples: 1,2,3,4,5,6,7,8.

Habitat: Deep, well-drained red loam on outcrops of Hawkesbury Shale. Flat ridgetops and adjacent slopes.

Distribution: 176 ha (1.9% of study area). Restricted to patches on broad ridges in the eastern third of the catchment.

Trees: 20 m tall, 39% cover; *Eucalyptus globoidea* is exclusive to this community. *Angophora costata, E. piperita* and *E. gummifera* co-occur in various combinations. Rare occurrences of *Eucalyptus saligna.*

Shrubs: 5 m tall, 13% cover; *Acacia binervata, A. longifolia, Pultenaea linophylla, P. hispidula* and *Olearia erubescens* are exclusive. Other common taxa include *Banksia spinulosa, Lomatia silaifolia, Phyllanthus hirtella, Ozothamnus diosmifolius, Hibbertia empetrifolia, Leucopogon lanceolata* and *Persoonia linearis.*

Groundcover: 0.8 m tall, 54% cover; dominated by grasses, forbs, vines and ferns. *Themeda australis, Pratia purpurascens, Pterostylis grandiflora, Viola betonicifolia, Goodenia heterophylla, Eustrephus latifolius, Kennedia rubicunda, Clematis aristata* and *Comesperma volubile* are exclusive. Other common taxa include *Imperata cylindrica, Dichelachne rara, Brunoniella pumilio, Lagenifera stipitata, Doryanthes excelsa, Lomandra longifloia, Lepidosperma laterale, Glycine clandestina, Blechnum cartilagineum* and *Calochlaena dubia.*

Variability: Samples on the Darkes Forest ridge are typified by a more mesic understorey than on smaller shale outcrops further west.

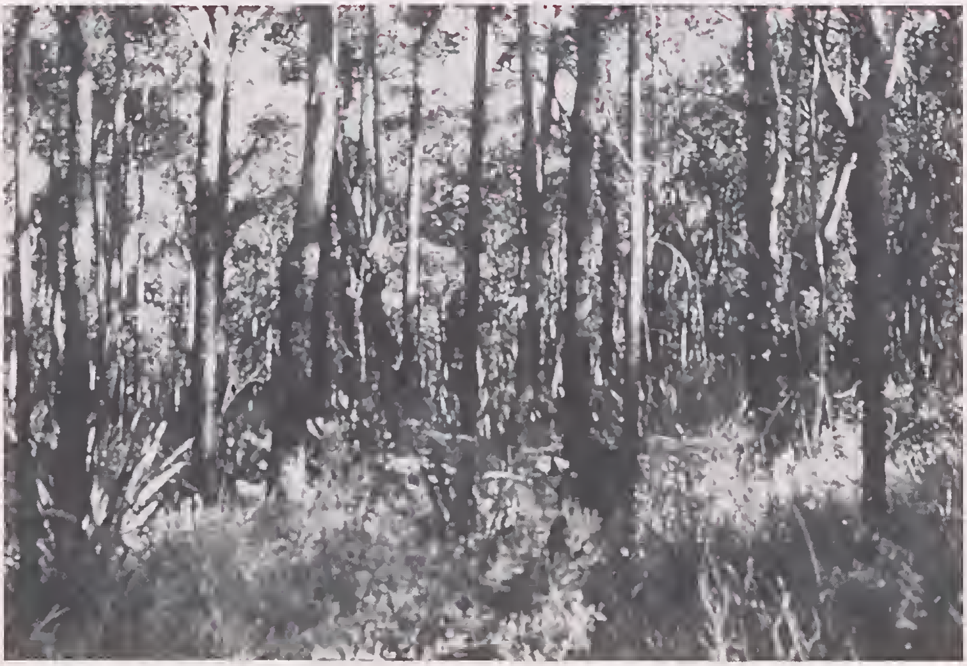

Figure 7. Shale Forest dominated by *Eucalyptus globoidea* with dense stands of *Doryanthes excelsa* and native grasses in the understorey.

Disturbance: Most stands have been selectively logged for fencing and firewood. The patch at Darkes Forest has been partly cleared for agricultural uses. Three other stands have been partly cleared for clay quarry operations.

Conservation: Shale Forest is important locally as habitat because it differs in markedly in composition and structure from surrounding vegetation on sandstone. Regionally, isolated stands of O'Hares Creek Shale Forest is transitional between more mesic escarpment forests on Narrabeen shales to the east and drier Cumberland Plain woodlands on Wianamatta shales to the west. However, widespread elements of the escarpment forests (e.g. *Eucalyptus pilularis, Syncarpia glomulifera*) and the plain woodlands (e.g. *Eucalyptus moluccana, Bursaria spinosa*) are absent from the O'Hares Creek Shale Forest, and some species found in the latter (e.g. *Pultenaea hispidula*) are poorly represented on the escarpment and plain. Forests occur on Hawkesbury Shale further north, but have a restricted distribution, and differ in floristic composition from those at O'Hares Creek (Table 6b). Such forests at Sutherland–Cronulla, Engadine, Frenchs Forest and Duffeys Forest have been cleared, while smaller patches such as those at Menai and Helensburgh retain forests under threat from urban development. Small, but differing stands are reserved near Loftus (Keith unpubl.) and near Wondabyne (Benson & Fallding 1981).

WGF Western Gully Forest

Samples: 9,10,11,26,33,34,35,36,43.

Habitat: Sheltered slopes of major sandstone gullies and restricted patches on narrow ridges (possibly with relictual shale influence). Soils are shallow, well-drained, moist sands and sandy loams.

Distribution: 822 ha (8.7% of study area). Gullies and adjacent ridges in western part of catchment.

Trees: 20 m tall, 31% cover; *Eucalyptus punctata* and *E. pilularis* occur exclusively in gullies in this community, while *E. consideniana* and *E. multicaulis* are exclusive to ridgetops. Other taxa include *E. agglomerata* and *Angophora costata* in gullies, and *E. gummifera* and *E. oblonga* on ridgetops.

Shrubs: 2.2 m tall, 43% cover; *Exocarpos strictus* and *Pomaderris lanigera* are exclusive. Other common taxa include *Banksia spinulosa, Dodonaea triquetra, Pultenaea flexilis, Lissanthe strigosa, Dillwynia retorta, Bossiaea heterophylla, Leptospermum trinervium* (narrow-leaved form), *Petrophile sessilis, Grevillea mucronulata, Persoonia linearis, P. levis, Platysace linearifolia* and *Eriostemon australasius*.

Groundcover: 0.4 m tall, 16% cover; *Aristida vagans* and *Xanthorrhoea concava* are exclusive. Other common taxa include *Acianthus fornicatus, Entolasia stricta, Caustis flexuosa* and *Pomax umbellata*.

Variability: In gullies the tree stratum is taller and includes *Eucalyptus punctata, E. pilularis, E. agglomerata* and *Angophora costata* (samples 11,26,33,35,36). Stands on ridges are restricted and include *E. consideniana, E. multicaulis, E. gummifera* and *E. oblonga* (samples 10,11,34,43).

Disturbance: Selective logging in small accessible areas.

Conservation: The community is likely to extend along the western edge of the Woronora Plateau to the Holsworthy Military Area in the north and Water Board catchments in the south. Similar communities may occur in conservation reserves in the Nattai area and lower Blue Mountains, although some differences in composition may be expected. Near Wedderburn, Western Gully Forest is habitat for a significant population of koalas (Cork et al. 1988, Close 1993).

EGF Eastern Gully Forest (Figure 8)

Samples: 23,25,27,28,29,30,31,32

Habitat: Sheltered slopes of major sandstone gullies. Soils are shallow, well-drained, moist sands and sandy loams.

Distribution: 1562 ha (16.6% of study area). Gullies in the eastern part of the catchment.

Trees: 20 m tall, 28% cover; *Eucalyptus piperita* with *Angophora costata, E. gummifera* and *E. sieberi*.

Shrubs: 3.0 m tall, 37% cover; *Banksia cunninghamii* is exclusive to this community. Other common taxa

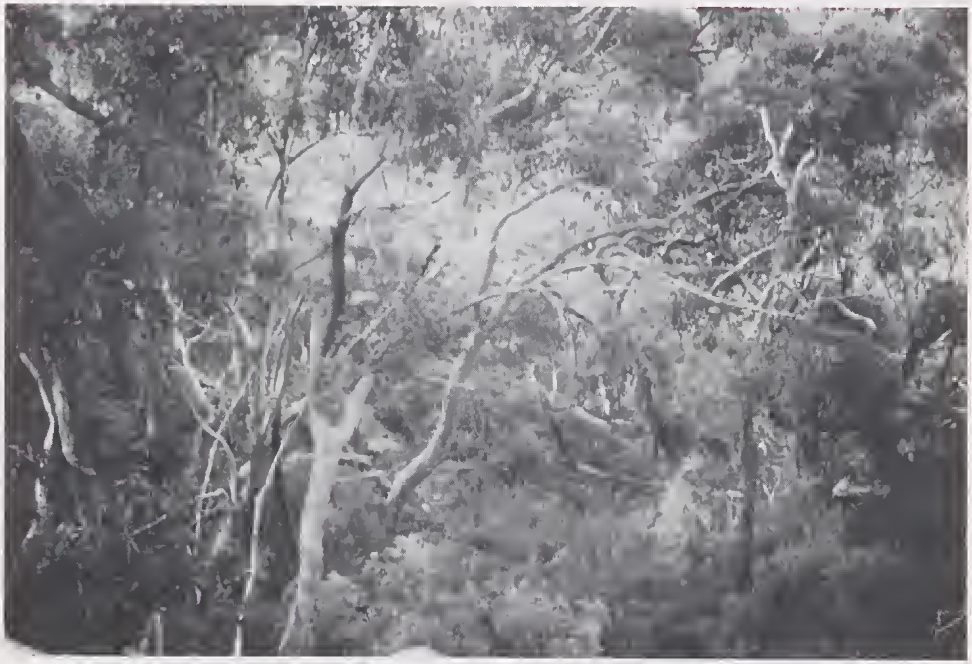

Figure 8. Eastern Gully Forest dominated by *Eucalyptus piperita* (foreground) and *Angophora costata* (smooth bark) with dense understorey of proteaceous, myrtaceous and fabaceous shrubs.

Figure 9. Riparian Scrub with *Leptospermum morrisonii, Tristaniopsis laurina* and other myrtaceous shrubs.

include *Aotus ericoides, Zieria laevigata, Hakea dactyloides* (single-stemmed form), *Monotoca scoparia, Hibbertia monogyna, Banksia serrata, Lambertia formosa, Persoonia pinifolia, P. levis, Platysace linearifolia, Acacia ulicifolia, Eriostemon australasius* and *Leptomeria acida.*

Groundcover: 0.7 m tall, 11% cover; *Lycopodium deuterodensum, Stylidium productum, Chloanthes stoechardis* and *Gahnia radula* are exclusive. Other common taxa include *Xanthosia pilosa* (entire-leafed form), *Gonocarpus teucrioides, Smilax glyciphylla, Cassytha pubescens, Lomandra gracilis, Patersonia glabrata, Lepidosperma laterale* and *Lepyrodia scariosa.*

Disturbance: No obvious disturbance.

Conservation: Similar vegetation is represented within Heathcote and Royal NPs (Keith unpubl. data). Forests in sandstone gullies further south are without *A. costata*, but otherwise similar. Reserves north and west of Sydney sample large areas of forest in sandstone gullies, but these differ in composition (Table 6a).

RS Riparian Scrub (Figure 9)

Samples: 19,20,21,22; outliers: 18,24.

Habitat: Moist, sandy alluvium amongst rocks along major creeks.

Distribution: 216 ha (2.3% of study area). O'Hares and Stokes Creeks and their major tributaries.

Trees: Typically none.

Shrubs: 4.1 m tall, 40% cover; *Tristaniopsis laurina, Tristania neriifolia, Leptospermum morrisonii, Ceratopetalum apetalum, Pseudanthus pimelioides, Lomatia myricoides, Prostanthera linearis, Phebalium dentatum, P. squamulosum* and *Micrantheum hexandrum* are exclusive to this community. Other common taxa include *Acacia obtusifolia, A. irrorata, Monotoca scoparia, Bauera rubioides* and *Grevillea longifolia.*

Groundcover: 0.6 m tall, 24% cover; *Lomandra fluviatilis* is exclusive. Other common taxa include *Restio dimorphus, Sticherus flabellatus, Lomandra longifolia* and *Lepidosperma laterale.*

Variability: Sheltered, rocky sites support tall scrub dominated by *T. laurina* and *C. apetalum*. Open sandy sites support heath with various smaller shrubs. Samples 18 & 24, on sandstone slopes adjacent to creeks, are intermediate in composition between Riparian Scrub and Eastern Gully Forest.

Disturbance: Small weirs on O'Hares and Stokes record stream flow. Each creek is also crossed by one ford. Otherwise, no evidence of disturbance. No exotic species recorded.

Conservation: Similar vegetation is represented in Royal and Heathcote NPs, as well as other sandstone reserves. However, O'Hares Creek catchment includes an example that is significant because of its condition, much riparian vegetation on Sydney sandstone being infested with weeds.

IW Ironstone Woodland (Figure 10)

Samples: 12,13,14,15.

Habitat: Flat areas of the plateau with a thick mantle of ironstone. Soils are well-drained red loams.

Distribution: 297 ha (3.2% of study area). Restricted to 2 main patches. Along 10B fire trail between Appin Rd and 10C fire trail and from the head of O'Hares Creek to Maddens Plains.

Trees: 13 m tall, 17% cover; *Eucalyptus sieberi* is most abundant in this community. Other common taxa include *E. racemosa* and *E. gummifera.*

Shrubs: 1.5 m tall, 44% cover; *Acacia myrtifolia, Daviesia corymbosa* and *Banksia paludosa* are most abundant in this community. Other common taxa include *Lambertia formosa, Hakea dactyloides* (multi-stemmed form), *Persoonia levis, Gompholobium grandifolium* and *Pimelea linifolia.*

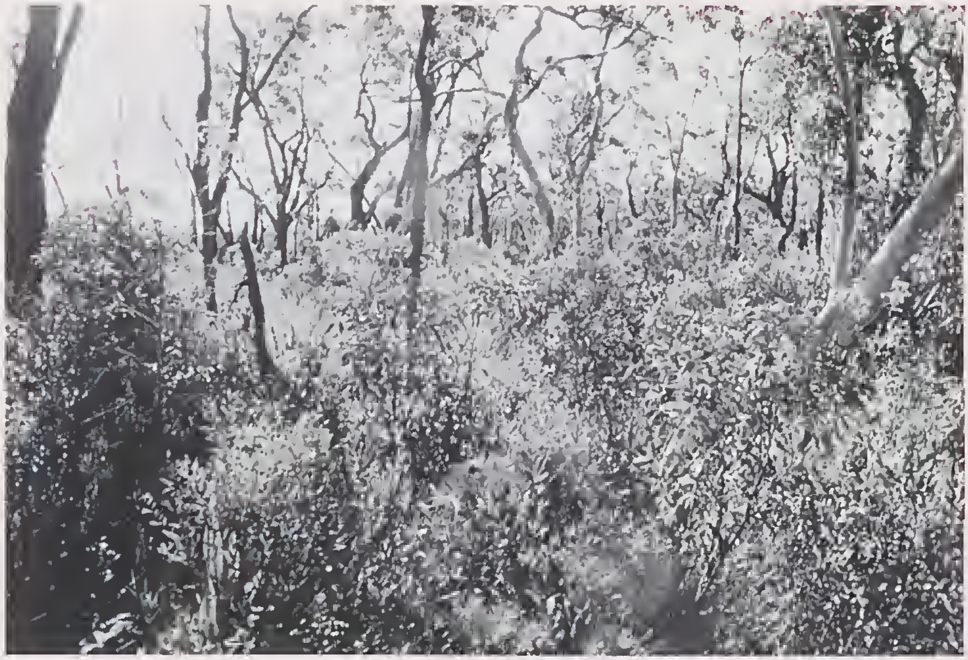

Figure 10. Ironstone Woodland with *Eucalyptus sieberi* (left), *E. racemosa* (right) and mallee *E. gummifera*. The understorey is dominated by shrubs in the Fabaceae and Proteaceae.

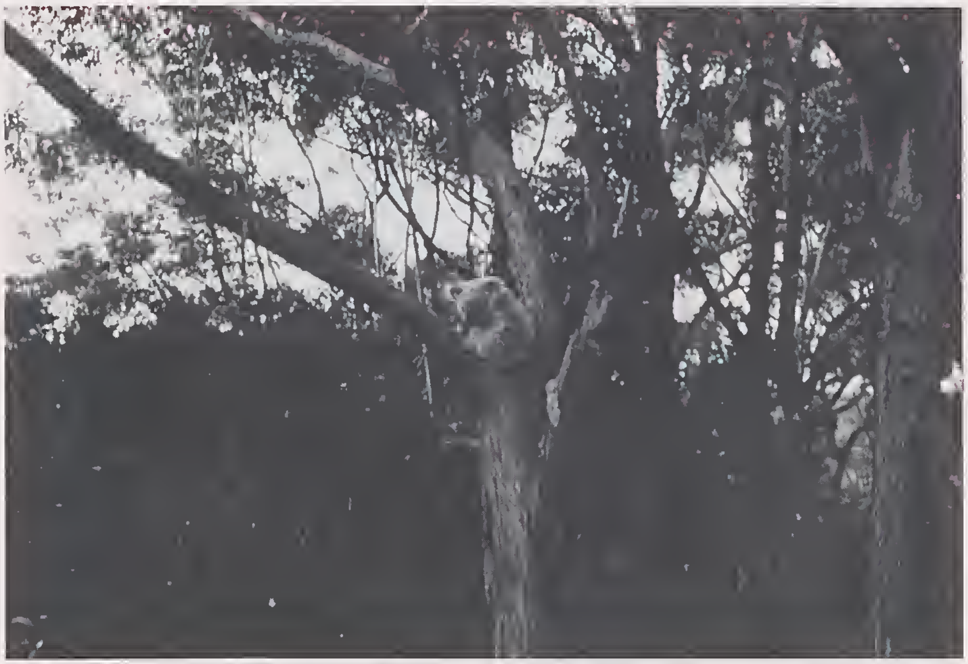

Figure 11. Sandstone Woodland near Wedderburn with *Eucayptus gummifera* (right) and *E. oblonga* (centre) and a diverse shrubby understorey. Sandstone Woodland and Western Gully Forest provide habitat for a population of koalas in this area.

Groundcover: 0.4 m tall, 23% cover; *Dampiera stricta, Gonocarpus tetragynus, Patersonia glabrata* and *Anisopogon avenaceus.*

Disturbance: Small borrow pits for gravel.

Conservation: Limited stands of similar vegetation in Royal NP (Keith unpubl. data), Garigal NP (map unit 11, Sherringham & Sanders 1993), Ku-ring-gai Chase NP (comm. 10, Thomas & Benson 1985) and around Warrah trig in Brisbane Water NP (comm. 4P, Benson & Fallding 1981).

SW Sandstone Woodland (Figure 11)

Samples: 37,38,42,47; outliers 39,40.

Habitat: Flat and undulating sandstone ridges and plateau tops. Soils are well-drained shallow sandy loams.

Distribution: 4446 ha (47.2% of study area). Widespread throughout catchment.

Trees: 9.5 m tall, 22% cover; *Eucalyptus oblonga* is characteristic of this community. Other trees include *E. gummifera, E. racemosa* and *E. sieberi.*

Shrubs: 1.2 m tall, 35% cover; *Bossiaea obcordata* is exclusive. Other common taxa include *Banksia spinulosa, B. marginata, B. serrata, Conospermum longifolium var. angustifolium, Grevillea sphacelata, Persoonia pinifolia, P. levis, Leptospermum trinervium* (narrow-leaved form), *Platysace ericoides, Hakea dactyloides* (multi-stemmed form), *Isopogon anemonifolius, Bossiaea heterophylla, Eriostemon australasius* and *Phyllota phylicoides.*

Groundcover: 0.4 m tall, 23% cover; common taxa include *Caustis flexuosa, Dampiera stricta, Lomandra glauca, Xanthorrhoea media* and *Cyathochaeta diandra.*

Variability: Closely related to Mallee Heath and Ironstone Woodland. Samples 39 & 40 are less clearly differentiated from these related communities than the other four samples.

Disturbance: Localised clearing for mine ventilation shafts, otherwise no obvious disturbance.

Conservation: Similar vegetation is represented within Royal, Heathcote and Garrawarra NPs and in Water Board catchments elsewhere on the Woronora Plateau (Keith unpubl. data). Analogous communities are widespread on sandstone plateaux north and west of Sydney (e.g. comm. 6 of Benson & Fallding (1981), 15 of Thomas & Benson (1985), C2 of Clarke & Benson (1986), 10ar of Keith & Benson (1988), map unit 7 of Sherringham & Sanders (1993)).

HW Heath Woodland

Samples: 44,45,46.

Habitat: Broad, flat plateau tops with an ironstone mantle overlying sandstone. Soils are damp, shallow sandy loams.

Distribution: 156 ha (1.7% of study area). Two main patches: along 10B fire trail between its junction with 10C and 10K trails; and along 10H fire trail near its junction with Darkes Forest Road.

Trees: 9.0 m tall, 7% cover; *Eucalyptus haemastoma* is dominant, *E. gummifera* in its mallee growth form is common, infrequent taxa include *E. racemosa, E. sieberi* and *E. oblonga.*

Shrubs: 1.2 m tall, 38% cover; *Petrophile pulchella, Banksia oblongifolia, Persoonia pinifolia, Hakea dactyloides* (multi-stemmed form), *Pimelea linifolia, Isopogon anemonifolius, Lambertia formosa, Grevillea oleoides, Hemigenia purpurea, Leucopogon esquamatus* and *Leptospermum trinervium* (broad-leaved form) are common taxa.

Groundcover: 0.4 m tall, 37% cover; *Patersonia glabrata, P. sericea, Lindsaea linearis, Lomandra obliqua, Cyathochaeta diandra, Lepyrodia scariosa, Ptilanthelium deustum, Schoenus pachylepis, Leptocarpus tenax, Mitrasacme polymorpha, Dampiera stricta, Xyris gracilis* ssp. *laxa, Xanthorrhoea media, Gonocar-*

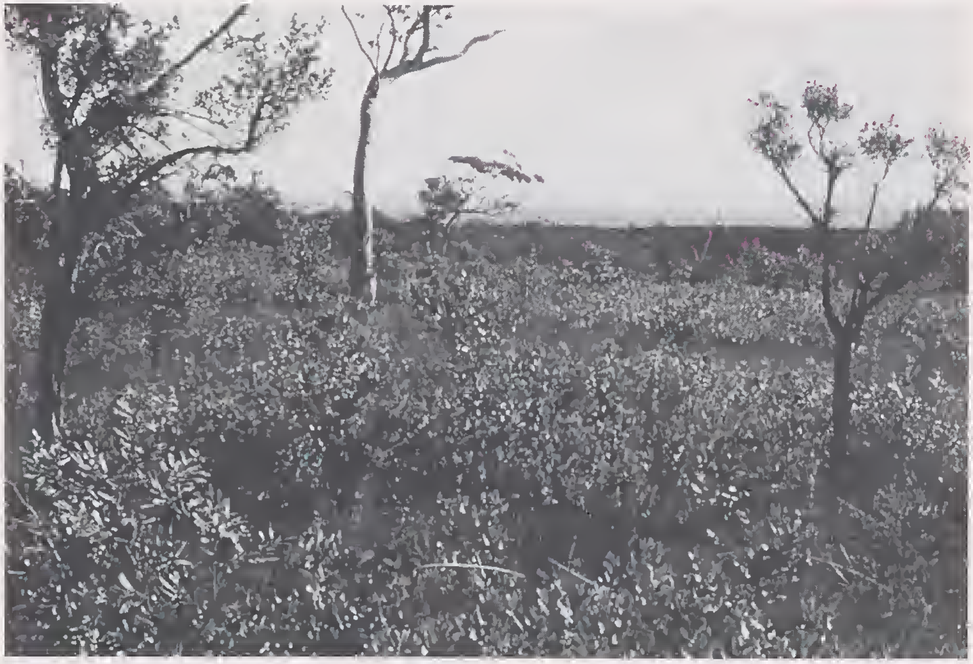

Figure 12. Ironstone Heath dominated by *Angophora hispida, Banksia oblongifolia* (bottom left) and emergent *Leptospermum trinervium*. Groundcover consists of graminoid and lilioid taxa.

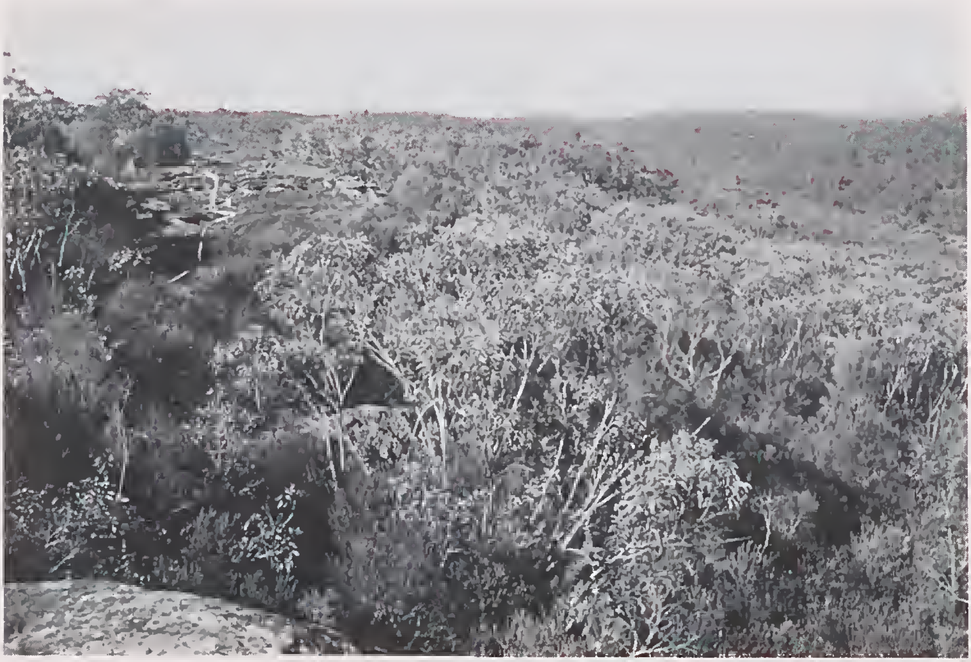

Figure 13. Mallee Heath dominated by *Eucalyptus luehmanniana. Banksia ericifolia* is conspicuous in the diverse understorey.

pus tetragynus, Anisopogon avenaceus, Actinotus minor, Mirbelia rubiifolia, Cassytha glabella, Selaginella uliginosa, Goodenia bellidifolia, Xanthosia tridentata, Thysanotus juncifolius and *Drosera peltata* are common taxa.

Disturbance: Localised patches cleared for army bivouacs.

Conservation: Limited stands represented in Royal NP (Keith unpubl. data). Larger stands in the Menai-Holsworthy area. Analogous vegetation types have been described on the Hornsby Plateau, but these are restricted in area (e.g. community C3 of Clarke & Benson (1986), map unit 6 of Sanders & Sherringham (1993)).

IH Ironstone Heath (Figure 12)

Samples: 16,17.

Habitat: Broad, flat plateau top with an ironstone mantle overlying sandstone. Soils are damp, shallow sandy loams.

Distribution: 12 ha (0.1% of study area). One small patch near 10B trig.

Shrubs: 1.0 m tall, 50% cover; *Angophora hispida, Hakea dactyloides* (multi-stemmed form), *Lomatia silaifolia, Pultenaea elliptica* (red-flowered form), *Conospermum taxifolium, Brachyloma daphnoides, Kunzea capitata* and *Eucalyptus haemastoma* are characteristic of this community. Other common taxa include *Hibbertia serpyllifolia, Acacia suaveolens, Leptospermum arachnoides, Petrophile pulchella, Pimelea linifolia, Isopogon anemonifolius, Lambertia formosa, Banksia oblongifolia, B. paludosa, Daviesia corymbosa, Grevillea oleoides, Persoonia levis, Platysace linearifolia, Eriostemon australasius, Leucopogon esquamatus* and *Leptospermum trinervium* (broad-leaved form).

Groundcover: 0.5 m tall, 20% cover; *Cyathochaeta diandra, Ptilanthelium deustum, Schoenus pachylepis, Patersonia glabrata, P. sericea, Scaevola ramosissima, Platysace ericoides, Dampiera stricta, Lomandra glauca, L. obliqua, Xyris gracilis* ssp. *laxa, Xanthorrhoea media, Gonocarpus tetragynus, Anisopogon avenaceus, Lindsaea linearis, Haemadorum corymbosum, Lepyrodia scariosa, Tricostularia pauciflora, Mirbelia rubiifloia, Cassytha glabella, Xanthosia tridentata, Drosera peltata, Burchardia umbellata, Sowerbaea juncea* and *Blandfordia nobilis*.

Variability: Closely related to woodland heath, but treeless.

Disturbance: Small area cleared for road gravel extraction.

Conservation: Larger areas in the north of Holsworthy Military Area to Menai area. Several patches represented in Royal NP, though these heathlands are more variable in composition (Keith unpubl. data). Heathlands in Ku-ring-gai Chase, Dharug and Garrigal NFs share some species, but differ in overall composition (Thomas & Benson 1985, Sherringham & Sanders 1993, Clarke & Benson 1986).

MH Mallee Heath (Figure 13)

Sites: 41,48,49,50,52.

Habitat: Stoney sandstone ridgetops with shallow, well-drained sandy loams.

Distribution: 28 ha (0.3% of study area). Small patches scattered in eastern part of catchment.

Trees: 4.8 m tall, 22% cover; *Eucalyptus luehmanniana* is characteristic of this community, *E. gummifera* (mallee growth form) is common.

Shrubs: 1.2 m tall, 35% cover; *Leucopogon microphyllus, Epacris microphylla, Leptospermum trinervium* (narrow-leaved form), *L. arachnoides, Monotoca scoparia, Acacia suaveolens, Petrophile pulchella, Hakea dactyloides* (multi-stemmed form), *Pimelea linifolia, Banksia ericifolia, B. serrata, B. oblongifolia, Hibbertia serpyllifolia, Daviesia corymbosa, Grevillea oleoides, Acacia ulicifolia, Platysace linearifolia, Eriostemon australasius, Xanthosia tridentata* and *Kunzea capitata*.

Groundcover: 0.4 m tall, 23% cover; *Entolasia stricta, Scaevola ramosissima, Dampiera stricta, Lomandra glauca, L. obliqua, Xyris gracilis* ssp. *laxa, Xanthorrhoea media, Bossiaea ensata, Gonocarpus tetragynus, Anisopogon avenaceus, Lindsaea linearis, Cyathochaeta diandra, Actinotus minor* and *Lepyrodia scariosa.*

Variability: Closely related to Sandstone Woodland.

Disturbance: No obvious disturbance.

Conservation: Mallee heath dominated by *E. luehmanniana* and *E. gummifera* is represented within Royal NP (Keith unpubl. data), Garrigal NP (map unit 5 of Sherringham & Sanders 1993), Ku-ring-gai Chase NP (community 16 of Thomas & Benson 1985) and Brisbane Water NP (part of community 6 of Benson & Fallding 1981). However, there are minor differences in understorey floristics and the community is locally restricted in these areas, as it is in O'Hares Creek catchment where it reaches its southern limit.

RPH Rock Pavement Heath

Sites: 51,53,54,55,56.

Habitat: Massive sandstone pavements on the plateau. Soils are skeletal, sandy and damp to very dry, depending on recent weather.

Distribution: 11 ha (0.1% of study area). Restricted to a few very small patches in the eastern and southern part of the catchment.

Shrubs: 1.5 m tall, 35% cover; *Monotoca ledifolia* is exclusive to this community. Characteristic taxa include *Kunzea ambigua* and *Darwinia fascicularis. Persoonia pinifola* is also present.

Groundcover: 0.5 m tall, 9% cover; *Lepidosperma viscidum* (red-gum form) and *Thelionema umbellatum* are exclusive. *Lepyrodia scariosa* is also present.

Variability: Few species occur consistently across most sites.

Disturbance: No obvious disturbance.

Conservation: Similar heath occurs in Royal NP (Keith unpubl. data). Heath on rock pavements north of Sydney differs in some of the major species (notably *Baeckea* spp.). Examples include community 18 of Thomas & Benson (1985), map unit 1 of Sherringham & Sanders (1993), community C5 of Clarke & Benson (1986) and community 9 of Benson & Fallding (1981). All these communities are highly restricted.

BT Banksia Thicket

Sites: S3,S14,S18,S31,S37,S48,S53.

Habitat: Upper slopes of large upland swamps. Soils are damp, shallow sandy loams.

Distribution: 95 ha (1.0% of study area). Patches restricted to southern part of catchment.

Shrubs: 3.4 m tall, 75% cover; *Banksia ericifolia* and *Hakea teretifolia* (single-stemmed form) are dominant and, with *Pultenaea aristata*, characteristic of this community. Other common taxa include *Banksia oblongifolia, Dillwynia floribunda* and *Grevillea oleoides.*

Groundcover: 0.6 m tall, 55% cover; *Tetrarrhena turfosa, Selaginella uliginosa, Lindsaea linearis, Empodisma minus, Gonocarpus tetragynus, Dampiera stricta, Lepidosperma neesii, Ptilanthelium deustum, Leptocarpus tenax, Lepyrodia scariosa, Schoenus brevifolius, Cassytha glabella, Entolasia stricta* and *Xanthorrhoea resinifera.*

Variability: Distribution, structure and composition vary depending on fire history. Frequent fires eliminate the overstorey or reduce its density (Keith 1991). Some stands include emergent eucalypts of Sandstone Woodland.

Disturbance: No obvious disturbance.

Conservation: Examples further south may be limited. Analogous communities further north in Royal NP (Keith unpubl. data), Ku-ring-gai Chase NP (community 17 of Thomas & Benson 1985), Garrigal NP (map unit 3 of Sherringham & Sanders 1993) and Brisbane Water NP (community 8 of Benson & Fallding 1981). However, these latter communities differ in composition, notably in the presence of *Allocasuarina distyla* as co-dominant.

SHC Sedgeland-Heath Complex (Figure 14)

– RH. Restioid Heath

Sites: S4,S6,S8,S9,S17,S2,S32,S36,S38,S39,S44,S47,S51,S52,S55.

Habitat: Damp upper slopes of large upland swamps or widespread in swamps without major seepage zones. Soils are occasionally waterlogged shallow sandy loams.

Distribution: Patches scattered throughout the south and east of the catchment. Restioid Heath occupies ca. 60% of the Heath-Sedgeland Mosaic (860 ha, 9.1% of study area).

Shrubs: 0.9 m tall, 38% cover; *Banksia oblongifolia, Hakea teretifolia* (multi-stemmed form), *Cryptandra ericoides* and *Grevillea parviflora* are characteristic of this community. Other common taxa include *Grevillea oleoides, Conospermum ellipticum, Bauera microphylla* and *Epacris obtusifolia*.

Groundcover: 0.6 m tall, 77% cover; *Lomandra filiformis* ssp. *filiformis, L. cylindrica, Plinthanthesis paradoxa, Burchardia umbellata, Patersonia* sp. aff. *fragilis, P. sericea and Haemadorum corymbosum* are characteristic. Other common taxa include *Stackhousia nuda, Thysanotus juncifolius, Lepidosperma neesii, Lindsaea linearis, Gonocarpus tetragynus, Dampiera stricta, Drosera spathulata, Goodenia bellidifolia, G. dimorpha* var. *angustifolia, Stylidium lineare, Sowerbaea juncea, Blandfordia nobilis, Mitrasacme polymorpha, Ptilanthelium deustum, Leptocarpus tenax, Lepyrodia scariosa, Empodisma minus, Schoenus*

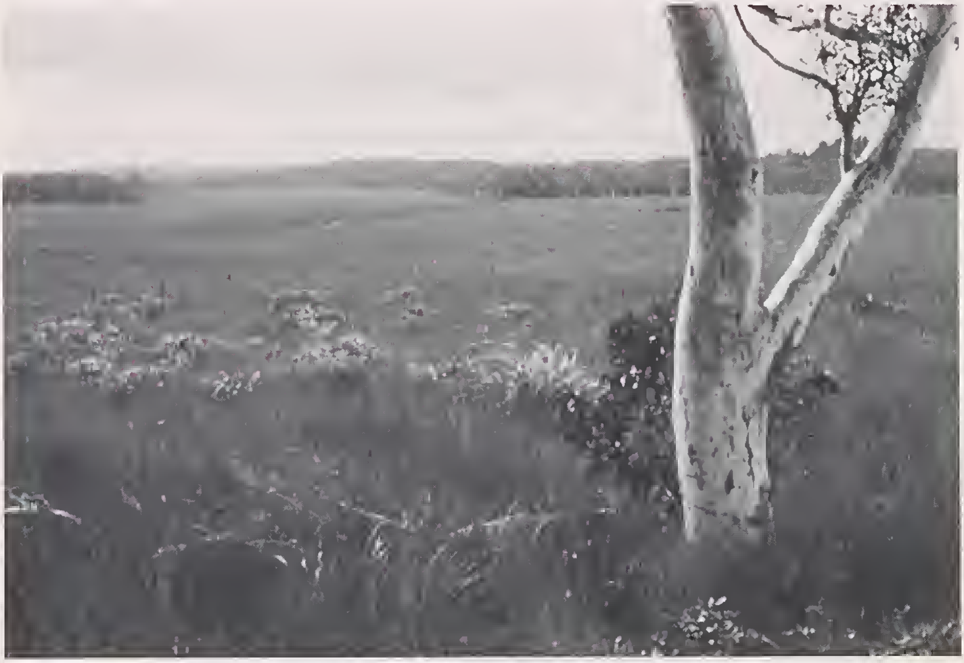

Figure 14. Sedgeland-Heath Complex at Maddens Plains showing Restioid Heath (foreground) with *Xanthorrhoea resinifera* and *Banksia oblongifolia*, grading into Cyperoid Heath (middle distance). The drainage line in the distance supports Ti-tree Thicket.

brevifolius, Cassytha glabella, Entolasia stricta, Xanthorrhoea resinifera, Xyris gracilis ssp. *laxa* and *X. operculata*.

Disturbance: Small patches excavated for clay extraction, otherwise undisturbed.

Conservation: Common in Water Board catchments on Woronora Plateau. Limited examples in Royal NP (Keith unpubl. data), on Lambert Peninsula in Ku-ring-gai Chase NP (Buchanan 1980) and around Kariong (part of community 12 of Benson & Fallding 1981).

– SL Sedgeland

Sites: S2,S5,S7,S20,S27,S29,S30,S33,S41,S43,S50,S56,S59.

Habitat: Seepage slopes perched on sandstone benches or on the sides of large upland swamps. Soils are sandy, humic sandy loams.

Distribution: Small patches mainly in the eastern part of the catchment. Sedgeland occupies about 10% of the Heath-Sedgeland Mosaic (860 ha, 9.1% of study area).

Shrubs: 0.9 m tall, 29% cover; *Sprengelia incarnata, Bauera microphylla, Symphionema paludosum, Baeckea imbricata* and *Boronia parviflora* are characteristic of this community. Other common taxa include *Epacris obtusifolia* and *Almaleea paludosa*.

Groundcover: 0.6 m tall, 69% cover; *Lepidosperma filiforme* and *Schoenus paludosum* are characteristic.. Other common taxa include *Ptilanthelium deustum, Leptocarpus tenax, Lepyrodia scariosa, Schoenus brevifolius, Cassytha glabella, Entolasia stricta, Drosera spathulata, Goodenia dimorpha* var. *angustifolia, Stylidium lineare, Xyris operculata, Empodisma minus* and *Chorizandra sphaerocephala*.

Disturbance: No obvious disturbance.

Conservation: Very localised on the Woronora Plateau. Representation within Royal NP is likely to be very limited.

– CH Cyperoid Heath

Sites: S1,S10,S11,S12,S13,S19,S25,S26,S28,S34,S40,S42,S45,S49,S57,S58

Habitat: Periodically waterlogged seepage zones in upland swamps. Soils are moderately deep gleyed organic sands and sandy loams.

Distribution: Southern and eastern parts of the catchment. Cyperoid Heath occupies about 30% of the Heath–Sedgeland Mosaic (860 ha, 9.1% of study area).

Shrubs: 1.4 m tall, 34% cover; Characteristic taxa include *Banksia robur, Hakea teretifolia* (multi-stemmed form), *Leptospermum juniperinum, Almaleea paludosa* and *Epacris obtusifolia*.

Groundcover: 1.0 m tall, 86% cover; characteristic taxa include *Lepidosperma limicola, Gymnoschoenus sphaerocephalus, Selaginella uliginosa* and *Xyris ustulata*. Other common taxa include *Xyris operculata, Tetrarrhena turfosa, Baumea teretifolia, Chorizandra sphaerocephala, Empodisma minus, Leptocarpus tenax, Schoenus brevifolius, Entolasia stricta* and *Xanthorrhoea resinifera*.

Disturbance: Small patches excavated for clay extraction, otherwise undisturbed.

Conservation: Most common on eastern Woronora Plateau in Water Board catchments. Limited examples in Royal NP (Keith unpubl. data), on Lambert Peninsula in Ku-ring-gai Chase NP (Buchanan 1980) and around Kariong (part of community 12 of Benson & Fallding 1981).

TT Ti-Tree Thicket

Sites: S15,S16,S21,S23,S24,S35,S46,S54,S60.

Habitat: Waterlogged drainage lines in large upland swamps. Soils are deep, highly organic gleyed loams and clay loams.

Distribution: 51 ha (0.5% of study area). Scattered in southern and eastern parts of the catchment.

Shrubs: 2.5 m tall, 37% cover; Characteristic taxa include *Leptospermum juniperinum, L. grandifolium, Epacris paludosa, Banksia robur, Melaleuca squarrosa, Viminaria juncea* and *Acacia rubida*.

Groundcover: 1.6 m tall, 90% cover; *Gleichenia microphylla, G. dicarpa, Gahnia sieberiana, Lepyrodia anarthria* and *Baumea teretifolia* are characteristic. Other common taxa include *Chorizandra sphaerocephala, Empodisma minus* and *Tetrarrhena turfosa*.

Variability: The shrub stratum varies from dense to almost absent, depending on water table fluctuation and long-term fire history.

Disturbance: No obvious disturbance.

Conservation: Most common on eastern Woronora Plateau in Water Board catchments. Limited examples in Royal NP (Keith unpubl. data) and on Lambert Peninsula in Ku-ring-gai Chase NP (Buchanan 1980).

Appendix 2. Two-way table of non-swamp quadrat data. Data are cover-abundance values (Poore 1955). Nomenclature follows Harden (1990–1993).

Refer to Appendix 1 for abbreviations of plant community names. Read site numbers vertically. Refer to Keith & Myerscough (1993) for two-way table of swamp data.

Plant Community	SF	WGF	EGF	RS	IW	MH	SW	IH	HW	RPH
Site Number		34113323	23332222	121222	1111	45445	343434	11	444	55555
	12538746	943015663	31205897	849201	2354	12980	728790	67	456	13654
Acacia binervata	333-11-2	---------	--------	------	----	-----	------	--	---	-----
Eucalyptus globoidea	33333343	---------	--------	------	----	-----	------	--	---	-----
Pterostylis grandiflora	11--1---	---------	--------	------	----	-----	------	--	---	-----
Desmodium varians	-1--1---	---------	--------	------	----	-----	------	--	---	-----
Pultenaea linophylla	11--21--	---------	--------	------	----	-----	------	--	---	-----
Acacia longifolia longifolia	31-21---	---------	--------	------	----	-----	------	--	---	-----
Viola hederacea	-1-21---	---------	--------	-----1	----	-----	------	--	---	-----
Blechnum cartilagineum	12331---	---------	--------	11----	----	-----	------	--	---	-----
Calochlaena dubia	55232---	---------	------1-	21----	----	-----	------	--	---	-----
Gahnia clarkei	12------	---------	-1------	1----1	----	-----	------	--	---	-----
Hibbertia dentata	-2------	---------	--------	------	----	-----	------	--	---	-----
Hydrocotyle acutiloba	-21-----	---------	--------	------	----	-----	------	--	---	-----
Echinopogon ovatus	-1------	---------	--------	------	----	-----	------	--	---	-----
Tylophora barbata	-1------	---------	--------	------	----	-----	------	--	---	-----
Galium binifolium	-1------	---------	--------	------	----	-----	------	--	---	-----
Adiantum aethiopicum	-1------	---------	--------	------	----	-----	------	--	---	-----
Santalum obtusifolium	-1------	---------	--------	------	----	-----	------	--	---	-----
Vernonia cinerea	-1------	---------	--------	------	----	-----	------	--	---	-----
Billardiera scandens	1111---1	-1-------	1----1--	11----	111-	-----	11--1-	--	---	-----
Eustrephus latifolius	111-----	---------	--------	------	----	-----	------	--	---	-----
Ozothamnus diosmifolius	1-1-----	---------	--------	------	----	-----	------	--	---	-----

Rapanea variabile	1-------	---------	--------	------	----	-----	------	--	---	-----
Cryptostylis erecta	1-------	---------	--------	------	----	-----	------	--	---	-----
Persoonia mollis nectans	1-------	---------	--------	------	----	-----	------	--	---	-----
Hakea salicifolia	2-------	---------	--------	-----1	----	-----	------	--	---	-----
Oxylobium ilicifolium	2-------	-------1-	--------	------	----	-----	------	--	---	-----
Acianthus fornicatus	-1-111--	-11111--2	1---2---	------	---1	-----	1-1---	--	---	-----
Pterostylis longifolia	-1---1--	---------	----1---	------	----	-----	------	--	---	-----
Lomatia silaifolia	--1112-1	11---1-1-	--1-111-	------	1-11	---11	1-111-	11	1--	-----
Xylomelum pyriforme	-----2--	1i-----1-	------1-	------	1---	-----	------	--	---	-----
Olearia erubescens	-----2--	---------	--------	------	----	-----	------	--	---	-----
Glycine tabacina	-----1--	---------	--------	------	----	-----	------	--	---	-----
Persoonia laurina	-----1--	---------	--------	------	----	-----	------	--	---	-----
Banksia spinulosa spinulosa	--1-1222	323311111	211--111	------	1113	-11--	111121	--	-1-	-----
Entolasia stricta	-1221221	2-2422111	112-1111	1-1--2	1-22	111-1	--1-12	-1	1--	-----
Phyllanthus hirtellus	--111111	1-1-111-1	-----111	------	1---	-----	-11-1-	--	---	-----
Gompholobium latifolium	----1--1	---------	------1-	------	----	-----	------	--	---	-----
Hardenbergia violacea	----1--1	----1-1--	------11	------	----	-----	------	--	---	-----
Poranthera corymbosa	----1---	---------	--------	------	--1-	-----	-1----	--	---	-----
Lepidosperma lineare	----1---	--------1	--------	------	----	-----	------	--	---	-----
Poranthera microphylla	----1---	---------	--------	------	----	-----	------	--	---	-----
Brunoniella pumilio	--111211	---------	------1-	------	1--1	-----	------	--	---	-----
Hibbertia empetrifolia	1-121311	---------	--1---1-	--1---	1--1	-----	------	--	---	-----
Doryanthes excelsa	3--213-1	---------	1-1---1-	------	---3	-----	------	--	---	-----
Dianella caerulea	211212-2	---1--112	11----1-	-1---1	---1	-----	------	--	---	-----
Pteridium esculentum	111222-1	-----2112	111--111	-1---3	---1	-----	------	--	---	-----
Lomandra longifolia	11122232	---1-1--1	11111-2-	1111-2	---2	-----	------	--	---	-----
Kennedia rubicunda	1-11---1	---------	--------	------	----	-----	------	--	---	-----
Leucopogon lanceolatus	2-1111-1	---------	-----11-	11---1	----	-----	------	--	---	-----
Clematis aristata	-12111--	---------	--------	------	----	-----	------	--	---	-----
Pratia purpurascens	-111-1--	---------	--------	------	----	-----	------	--	---	-----

Glycine clandestina	-1111-1-	-----1---	--------	------	----	-----	------	--	---	-----
Dianella revoluta	--11----	-----1---	--------	------	----	-----	----1-	--	---	-----
Oxalis perennans	--11----	---------	--------	------	----	-----	------	--	---	-----
Pterostylis curta	---1----	---------	--------	------	----	-----	------	--	---	-----
Comesperma volubile	---111--	---------	--------	------	----	-----	------	--	---	-----
Viola betonicifolia	---11---	---------	--------	------	----	-----	------	--	---	-----
Themeda australis	---12---	---------	--------	------	----	-----	------	--	---	-----
Imperata cylindrica	-2-13121	-----4---	--------	------	----	-----	------	--	---	-----
Chionochloa pallida	------21	---------	--------	------	1---	-----	----4-	--	---	-----
Poa labillardieri	------2-	---------	--------	------	----	-----	------	--	---	-----
Dichelachne rara	1112--2-	---------	-----11-	------	----	-----	------	--	---	-----
Microlaena stipoides	--1---21	---------	-----11-	-1----	----	----1	----1-	--	---	-----
Goodenia heterophylla	--1-1111	---------	--------	------	----	-----	------	--	---	-----
Lagenifera stipitata	-1111111	---------	1----1--	------	1---	-----	----11	--	---	-----
Pultenaea hispidula	----1-1-	---------	--------	------	----	-----	------	--	---	-----
Daviesia ulicifolia	------1-	---------	--------	------	----	-----	------	--	---	-----
Goodenia hederacea	------1-	---------	-------1	------	1---	-----	------	--	---	-----
Lomandra multiflora	------1-	------11-	--------	------	1---	-----	-----1	--	-1-	-----
Chiloglottis reflexa	--1----1	---------	----1---	------	----	-----	------	--	---	-----
Pultenaea daphnoides	--1----2	---------	----1-1-	------	----	-----	------	--	---	-----
Hibbertia scandens	-11-----	---------	--------	------	----	-----	------	--	---	-----
Centella asiatica	--1-----	---------	--------	------	----	-----	------	--	---	-----
Oplismenus imbecillus	--1-----	---------	--------	------	----	-----	------	--	---	-----
Acacia stricta	--1-----	---------	--------	------	----	-----	------	--	---	-----
Entolasia marginata	--2-----	---------	--------	------	----	-----	------	--	---	-----
Opercularia aspera	--1-1---	--------1	----1-1-	11----	----	-----	------	--	---	-----
Tetraria capillaris	--1-1---	---------	------1-	------	----	-----	------	--	---	-----
Schoenus melanostachyus	--1-----	--------1	----111-	1--1-1	----	-----	------	--	---	-----
Acacia linifolia	------11	2---221--	1-1--111	---1--	----	----1	1---11	--	---	-----
Aristida vagans	--------	----22---	--------	------	----	-----	------	--	---	-----

Leucopogon ericoides	---------	11--11---	--1--1--	------	----	--1--	------	--	---	--1--
Lissanthe strigosa	---------	1---11---	--------	------	----	-----	--1---	--	---	-----
Xanthorrhoea concava	---------	-1--1-1--	--------	------	----	-----	------	--	---	-----
Eragrostis brownii	---------	----1----	--------	-----1	----	-----	------	--	---	-----
Cheilanthes sieberi	---------	----1----	--------	------	----	-----	------	--	---	-----
Dodonaea triquetra	---------	---1333-3	1----1--	--2--3	----	-----	------	--	---	-----
Eucalyptus punctata	---------	---3433-3	--------	------	----	-----	------	--	---	-----
Exocarpos strictus	---------	----113--	--------	------	----	-----	------	--	---	-----
Eucalyptus pilularis	---------	-----33--	--------	------	----	-----	------	--	---	-----
Cheilanthes distans	---------	------1--	--------	------	----	-----	------	--	---	-----
Danthonia longifolia	---------	------1--	--------	------	----	-----	------	--	---	1----
Banksia marginata	---------	--4------	---1----	------	----	-----	112---	--	---	----1
Conospermum longifolium	---------	--1------	--------	------	----	----1	1111--	--	---	----1
Schoenus ericetorum	---------	--1------	--------	------	----	1----	1-11--	--	---	----1
Grevillea sphacelata	---------	--1------	--------	------	1---	1-1--	11112-	--	---	----1
Caustis flexuosa	---------	2--211112	1--222-1	-1----	----	--111	2111-1	--	---	-----
Dillwynia retorta	---------	33311-111	-211-2-1	------	1---	---11	2-11-1	--	---	----1
Leptospermum trinervium (nl)	---------	-331132-1	-11211-2	--12--	---1	1421-	221212	--	---	----2
Grevillea buxifolia	---------	--11-----	--------	------	----	-----	--1---	--	---	-----
Melichrus urceolatus	---------	---------	--------	------	----	-----	--1---	--	---	-----
Grevillea diffusa diffusa	1--------	3-1-1----	2---12--	1-----	----	--11-	121--1	--	---	----1
Lomandra filiformis filiformis	---------	1--------	----11--	------	----	1----	--1---	--	---	-----
Eucalyptus multicaulis	---------	--31-----	--------	------	----	-----	------	--	---	-----
Petrophile sessilis	---------	1332-----	--------	------	----	-----	-11-21	--	---	----1
Hakea sericea	-------1-	1132-1--1	2-1-1---	-----1	-1--	-11--	111-1-	--	---	----2
Bossiaea obcordata	---------	---------	-------2	------	----	-----	-12-11	--	---	-----
Eucalyptus oblonga	---------	3-3-1----	-------1	------	21--	----1	222-12	--	-1-	-----
Mirbelia speciosa	---------	---------	--------	------	-1--	----1	111---	--	--1	-----
Schoenus turbinatus	---------	---------	--------	------	-1--	-----	11---1	--	---	-----
Boronia ledifolia	---------	--2-1--1-	--------	------	----	-----	1-----	--	---	-----

Caustis pentandra	--------	--1------	-1------	--1---	----	-----	------	--	---	1----
Gompholobium minus	--------	--1------	--------	------	----	-----	------	--	---	-----
Hovea linearis	--------	-11--1-1-	-----1--	------	-1-1	-----	----1-	--	-1-	-----
Pomax umbellata	--------	111--1-11	-------1	------	----	-----	------	--	---	--1--
Acacia terminalis	--------	-1-1-1112	11-1211-	-1----	--1-	--1-1	-----1	--	---	1----
Xanthosia pilosa (el)	----1---	11----112	11111111	------	----	--1--	1-----	--	---	-----
Hakea dactyloides (ss)	--------	1----1121	1-1112--	---1-1	----	-----	------	--	---	-----
Ricinocapus pinifolius	--------	-------1-	1--1----	------	----	-----	------	--	---	-----
Eucalyptus agglomerata	--------	-3---3333	---1-2--	-2---1	----	-----	------	--	---	-----
Pultenaea flexilis	--------	-1---314-	-----1--	------	----	-----	------	--	---	-----
Xanthorrhoea arborea	--------	-------11	----22-2	------	----	-----	------	--	---	-----
Stylidium laricifolium	--------	-------1-	-----1--	------	----	-----	------	--	---	-----
Liparis reflexa	--------	---------	-----1--	------	----	-----	------	--	---	-----
Angophora costata	443---33	33-311322	3-2-3333	24-1-1	----	-----	------	--	---	-----
Ceratopetalum gummiferum	-------1	31-1---21	1-1-1-1-	11----	----	-----	------	--	---	-----
Grevillea mucronulata	--------	31-1-3111	----211-	-1---1	----	-----	----1-	--	---	-----
Persoonia linearis	-1121--1	21---1111	----11--	11----	----	-----	------	--	---	-----
Dampiera purpurea	-1------	1--1-1---	----11-1	-----1	----	-----	------	--	---	-----
Eucalyptus consideniana	--------	1--1-----	--------	------	----	-----	------	--	---	-----
Callistemon linearis	--------	---1-----	--------	------	----	-----	------	--	---	-----
Amperea xiphoclada	--------	---------	11-11---	------	1-11	11---	------	--	---	-----
Leucopogon exolasius	--------	-------1-	---11---	-----1	----	-----	------	--	---	-----
Banksia cunninghamii	--------	---------	---11---	------	----	-----	------	--	---	-----
Petrophile pedunculata	--------	---------	----1---	------	----	-----	------	--	---	-----
Correa reflexa	--------	---------	----1---	------	----	-----	------	--	---	-----
Epacris longiflora	--------	---------	----1-1-	------	----	--11-	------	--	---	-----
Monotoca scoparia	--------	--1----1-	111-111-	--21-1	-1--	1111-	1111--	--	---	-1---
Leptomeria acida	---1---1	-1-----1-	1111111-	------	11-1	-----	111---	--	---	-----
Lycopodium deuterodensum	--------	---------	---1111-	------	----	-----	------	--	---	-----
Persoonia pinifolia	---11---	1--------	1211111-	1111-1	1--1	---11	2111-1	-1	111	1--12

Patersonia glabrata	---113--	--------1	111-1111	1-----	22-2	1-1-1	11-1-1	11	121	-----
Telopea speciosissmia	----11--	---------	----111-	------	11--	-----	1-----	--	---	-----
Aotus ericoides	--------	---------	22123-1-	------	----	1-1--	-----1	--	---	-----
Eucalyptus piperita	233-23--	-1-------	33333333	22----	----	-----	------	--	---	-----
Empodisma minus	--------	---------	111-----	------	----	--1--	------	--	1--	-1---
Gleichenia dicarpa	--------	---------	11------	------	----	-----	------	--	---	-----
Exocarpos cupressiformis	--------	---------	-1------	------	----	-----	------	--	---	-----
Gonocarpus teucrioides	----1---	1--2-----	11111-2-	1-1---	---1	--1--	-----1	--	---	-----
Smilax glyciphylla	1-1-1---	-1------1	1111111-	112---	---1	--11-	------	--	---	-----
Cassytha pubescens	-----1--	112------	1111-11-	-12---	11--	-----	--11-1	--	---	---1-
Zieria laevigata	--------	---------	111--11-	-1----	----	-----	------	--	---	-1---
Gahnia radula	--------	---------	1-----1-	------	----	-----	------	--	---	-----
Lomandra gracilis	--1--11-	----2--1-	1111-11-	------	----	--11-	--1---	--	---	-----
Tetrarrhena turfosa	-11--2--	---------	1--1-11-	-1----	---1	--1--	------	--	---	-----
Lomandra cylindrica	--------	12----1-1	1----111	------	-1--	1----	-----1	1-	--1	----1
Isopogon anethifolius	--------	---------	1-------	------	----	-----	------	1-	---	-----
Styphelia tubiflora	--------	---------	1-------	------	----	-----	------	--	---	-----
Wahlenbergia gracilis	--------	---------	1-------	------	----	-----	------	--	---	-----
Pultenaea scabra	--------	2--------	1-1-----	------	---1	-----	------	--	---	-----
Hibbertia monogyna	--------	---------	2-11-1-1	------	----	1----	------	--	---	-----
Woollsia pungens	--------	---------	--11-1--	------	----	-----	-1----	--	---	-----
Stylidium productum	--------	---------	--1--1--	------	----	-----	------	--	---	-----
Tetratheca shiressii	--------	---------	--1-----	------	----	-----	------	--	---	-----
Schizea bifida	--------	---------	--1----1	------	----	-----	------	-1	-1-	-----
Lomandra filiformis coriacea	-----1-1	----1----	-----1-1	------	1-1-	1----	-----1	--	---	-----
Thysanotus tuberosus	--------	---------	-----1-1	------	----	-----	-1---1	--	---	-----
Chloanthes stoechardis	--------	---------	-----1-1	------	----	-----	------	--	---	-----
Choretrum candollei	--------	---------	-------1	------	----	-----	------	--	---	-----
Bauera rubioides	--------	---------	--11--1-	1--111	----	-----	------	--	---	-----
Gleichenia microphylla	--------	---------	---1--1-	1--2-2	----	-----	------	--	---	-----

Gahnia sieberiana	--------	---------	--11----	------	----	-----	------	--	---	---1-
Stylidium graminifolium	--------	---------	---1----	------	----	-----	------	--	---	-----
Leucopogon amplexicaule	--------	---------	---1----	------	----	-----	------	--	---	-----
Notelaea longifolia	---1----	---------	--------	1---1-	----	-----	------	--	---	-----
Todea barbara	--------	---------	--------	----1-	----	-----	------	--	---	-----
Dendrobium speciosum	--------	---------	-----1--	1-----	----	-----	------	--	---	---1-
Adiantum hispidulum	--------	---------	--------	1-----	----	-----	------	--	---	-----
Lindsaea microphylla	--------	---------	-----11-	11----	----	-----	------	--	---	-----
Logania albiflora	--------	---------	------1-	11----	----	-----	------	--	---	-----
Marsdenia suaveolens	--------	--------1	-1---1--	11----	----	-----	------	--	---	-----
Epacris pulchella	------1-	---1-----	11-1-1--	11----	----	----1	------	--	---	-----
Lepidosperma laterale	1--1-211	---1-1---	11-111--	1211-1	----	-----	21----	--	---	-----
Dracophyllum secundatum	--------	---------	-1--1---	-1----	----	-----	------	--	---	-----
Elaeocarpus reticulatus	-----1--	---------	-1------	-1----	----	-----	------	--	---	-----
Helichrysum elatum	11------	---------	--------	-1----	----	-----	------	--	---	-----
Hymenophyllum cupressiforme	--------	---------	--------	-1----	----	-----	------	--	---	-----
Olearia viscidula	--------	---------	--------	-1----	----	-----	------	--	---	-----
Lepidosperma urophorum	--------	---------	--------	-1----	----	-----	------	--	---	-----
Pultenaea blakelyi	--------	---------	--------	-31---	----	-----	------	--	---	-----
Tristaniopsis collina	--------	---------	--------	-3----	----	-----	------	--	---	-----
Acrotriche divaricata	--------	---------	--------	-2----	----	-----	------	--	---	-----
Pomaderris lanigera	--------	-----1-13	--------	------	----	-----	------	--	---	-----
Callitris rhomboidea	--------	--------3	--------	------	----	-----	------	--	---	-----
Eriostemon scaber	--------	-------12	--------	------	----	-----	------	--	---	-----
Dendrobium linguiforme	--------	-------11	--------	------	----	-----	------	--	---	-----
Grammitis billardieri	--------	--------1	--------	------	----	-----	------	--	---	-----
Platycerium bifurcatum	--------	--------1	--------	------	----	-----	------	--	---	-----
Cassinia aureonitens	--------	--------1	--------	------	----	-----	------	--	---	-----
Zieria cytisoides	--------	--------1	--------	------	----	-----	------	--	---	-----
Platysace lanceolata	--------	--------1	--------	------	----	---1-	------	--	---	-----
Acacia obtusifolia	--------	-------12	---1111-	213413	----	-----	------	--	---	-----

Leptospermum morrisonii	--------	---------	--------	1-2413	---1	-----	------	--	---	-----
Pseudanthus pimelioides	--------	---------	--------	--13-1	----	-----	------	--	---	-----
Tristaniopsis laurina	--------	---------	--------	--43-1	----	-----	------	--	---	-----
Lomandra fluviatilis	--------	---------	--------	--232-	----	-----	------	--	---	-----
Tristania neriifolia	--------	---------	--------	1-324-	----	-----	------	--	---	-----
Phebalium dentatum	--------	---------	--------	--111-	----	-----	------	--	---	-----
Lomatia myricoides	--------	---------	--------	3-3221	----	--1--	------	--	---	-----
Sticherus flabellatus	2-------	---------	--------	3-311-	----	-----	------	--	---	-----
Micrantheum hexandrum	--------	---------	--------	--31-4	----	-----	------	--	---	-----
Restio dimorpha	--------	---------	--------	--21-2	----	----2	------	--	---	-----
Stenocapus salignus	--------	---------	--------	--3---	----	-----	------	--	---	-----
Bossiaea rhombifolia	--------	---------	--------	--2---	----	-----	------	--	---	-----
Allocasuarina littoralis	1-------	-------41	1-1---1-	--23--	----	-----	------	--	---	-----
Ceratopetalum apetalum	--------	---------	--------	4131-1	----	-----	------	--	---	-----
Phebalium squamulosum squamulosum	--------	---------	--------	211--1	----	-----	------	--	---	-----
Hibbertia nitida	--------	---------	---1----	1-1--1	----	-----	------	--	---	-----
Prostanthera linearis	--------	---------	--------	1-2--1	----	-----	------	--	---	-----
Acacia irrorata	--------	---------	--------	--1--1	----	-----	------	--	---	-----
Grevillea longifolia	--------	---------	--------	--1--1	----	-----	------	--	---	-----
Pomaderris intermedia	--------	---------	-----1--	-11--2	----	-----	------	--	---	-----
Pomaderris andromedifolia	--------	---------	--------	--1---	----	-----	------	--	---	-----
Backhousia myrtifolia	--------	---------	--------	-11---	----	-----	------	--	---	-----
Lasiopetalum ferrugineum	--------	-1------2	--------	-----1	----	-----	------	--	---	-----
Bertya pomaderroides	--------	---------	--------	-----1	----	-----	------	--	---	-----
Gonocarpus microphyllus	--------	---------	--------	-----1	----	-----	------	--	---	-----
Chorizandra cymbaria	--------	---------	--------	-----1	----	-----	------	--	---	-----
Westringia longifolia	--------	---------	--------	-----1	----	-----	------	--	---	-----
Callistemon citrinus	--------	---------	--------	---1-1	----	-----	------	--	---	-----
Leptospermum polygalifolium	--1-----	---3-----	--1---1-	1----1	----	--1-1	------	--	---	----1

Acacia myrtifolia	----111-	----1----	--------	------	3212	-----	2-1-11	--	11-	----1
Eucalyptus gummifera	---32322	32332-3--	-131--22	------	2343	34123	133233	--	122	11---
Eucalyptus racemosa	--------	---------	--------	------	2332	2----	23--33	--	1--	1----
Eucalyptus sieberi	-----1--	---------	-121---1	------	3333	3----	3-----	--	-1-	-----
Lobelia dentata	--------	---------	--------	------	---1	1----	----2-	--	---	-----
Stipa pubescens	---112--	---112---	------1-	------	11-1	-----	-1--21	--	---	-----
Haemadorum planifolium	--------	---------	--------	------	--1-	1----	----1-	--	---	-----
Viola sieberiana	--------	---------	--------	------	--1-	-----	------	--	---	-----
Mitrasacme polymorpha	--------	---------	--------	------	--1-	11---	----11	1-	111	-----
Scaevola ramosissima	--------	---------	-----1--	------	1-1-	111-1	----11	11	-1-	-----
Hypericum gramineum	---1--11	---------	--------	------	----	-----	----1-	--	---	-----
Deyeuxia decipiens	-------1	---------	--------	------	----	-----	----1-	--	---	-----
Opercularia varia	------11	---------	--------	--1---	--1-	-----	----2-	--	---	-----
Pelargonium inodorum	--------	---------	--------	------	----	-----	----1-	--	---	-----
Caesia vittata	--------	---------	--------	------	----	-----	----1-	--	---	-----
Leucopogon virgatus	--------	---------	--------	------	----	-----	----1-	--	---	-----
Caesia parviflora	--------	---------	--------	------	----	-----	-----1	--	1-1	-----
Hakea teretifolia (ss)	------1-	---------	--1-----	------	--1-	11---	-----1	--	1-1	1----
Goodenia dimorpha angustifolia	--------	---------	--------	------	----	-----	-----1	--	---	-----
Genoplesium nublingii	--------	---------	--------	------	----	-----	-----1	--	---	-----
Hybanthus monopetalus	--------	---------	--1---1-	------	--1-	-----	-1---1	--	11-	-----
Sphaerolobium vimineum	--------	---------	--------	------	----	--1--	-1---1	--	11-	1----
Platysace ericoides	------1-	---------	--------	------	----	-11--	11-122	11	1--	---1-
Thelymitra circumsepta	--------	---------	--------	------	----	-----	----11	-1	---	-----
Tricoryne simplex	--------	---------	--------	------	----	-----	----11	-1	1--	-----
Acacia suaveolens	--------	----1----	11-----1	------	11--	11111	11-11-	11	1-1	11---
Dampiera stricta	------11	1--------	--1--11-	------	1211	11111	111111	11	111	1----
Lomandra glauca	--------	----1----	--1--1--	------	12--	11111	1112-1	11	-11	---1-
Xyris gracilis laxa	--------	---------	--------	------	-1--	11111	11---1	11	111	-----

Leptospermum arachnoides	--------	---------	--------	------	--1-	11111	1-----	11	-1-	1--1-
Petrophile pulchella	--------	----1---1	1--2-1--	-----1	111-	11111	11-1--	11	121	1--1-
Xanthorrhoea media	--------	2-2------	---1----	------	111-	11111	11111-	11	111	1--1-
Bossiaea ensata	--------	--1------	--------	------	111-	11111	-1-1--	--	--1	----1
Gonocarpus tetragynus	---2----	--1------	--------	------	1111	11-11	-1-11-	11	111	-----
Hakea dactyloides (ms)	--------	---------	--------	------	1113	11111	-11111	12	111	-----
Anisopogon avenaceus	--------	-3-------	1111--1-	------	1112	111-1	-111-2	11	111	1----
Pimelea linifolia	--------	--1------	-1111---	------	1112	1111-	111--1	11	111	-----
Isopogon anemonifolius	--------	-111-----	1-1--1-1	------	11--	11--1	111111	11	111	-----
Lambertia formosa	--------	-21----1-	1111-1-1	-----1	1212	11---	1111--	11	111	-----
Banksia serrata	--------	-3---1--1	11111111	------	11--	11111	1121-1	1-	-1-	-----
Hibbertia stricta group	--------	---------	-111--1-	------	111-	11111	1111--	--	---	1----
Banksia paludosa	--------	---------	--1-----	------	-331	1---1	------	11	11-	-----
Daviesia corymbosa	--------	---------	-11-----	------	2113	1-111	---1--	11	12-	-----
Grevillea oleoides	--------	---------	-11-----	--11-4	1-12	11111	-1-1--	11	111	-----
Lindsaea linearis	----1--1	---------	--1-----	------	--11	11111	------	11	121	-----
Acacia ulicifolia	--------	21--112--	21-11--1	------	11--	1-111	1-11--	--	-1-	---1-
Lomandra obliqua	-------1	11---11--	11-1--11	------	-111	11111	1-1-1-	11	221	1--1-
Bossiaea heterophylla	--------	112-1-1-1	1--111--	------	11--	1-11-	1111-1	-1	11-	-----
Persoonia levis	-----111	21111-111	111-1111	------	1111	--1-1	111111	11	11-	-----
Platysace linearifolius	--------	21112-111	111-11-1	------	112-	11111	2111--	11	11-	-----
Eriostemon australasius	--------	12-11-11-	11-1-1-2	------	-1--	1111-	-11111	11	-1-	-----
Gompholobium grandiflorum	--------	2121-1---	1-1-----	------	1111	1-1-1	1-11--	--	-1-	-----
Tetratheca neglecta	--------	1-1------	--------	------	111-	--111	--11-1	--	-1-	-----
Phyllota phylicoides	--------	11-------	--------	------	----	-----	1-12--	1-	-1-	-----
Baeckea ramosissima	--------	---------	--------	------	----	-----	-1-1--	--	-1-	-----
Gompholobium glabratum	--------	---------	--------	------	----	---1-	-1-111	1-	--1	-----
Conospermum ellipticum	--------	---------	--------	------	----	-----	---1--	--	--1	-----
Caustis recurvata	--------	---------	--------	------	----	-----	---1--	--	---	-----
Cyathochaeta diandra	-----1--	-33-1----	-------1	------	2-11	112-3	121222	22	211	----1

Hemigenia purpurea	--------	---------	--------	------	----	--2-1	1--1--	1-	111	-----
Haemadorum corymbosum	--------	---------	--------	------	--1-	-1--1	1--1--	11	--1	-----
Pultenaea elliptica (yf)	--------	---------	--------	------	--1-	-12-1	12-11-	--	--1	----2
Actinotus minor	--------	--23-----	1--1-1--	1-----	-11-	11222	-1-1--	1-	111	1----
Leucopogon microphyllus	--------	---1-----	--------	------	----	11112	1--1--	1-	---	11---
Epacris microphylla	--------	---1-----	--1-----	------	----	-1222	11---1	-1	-12	1211-
Lepyrodia scariosa	--------	---3-----	11111-1-	--1---	--1-	22322	111---	11	213	12-2-
Eucalyptus luehmanniana	--------	---------	--------	------	----	-433-	---3--	--	---	-----
Pultenaea aristata	--------	---------	--------	------	----	-1-1-	------	--	---	-----
Darwinia grandiflora	--------	---------	--------	------	----	-1-1-	------	--	---	-----
Baeckea diosmifolia	--------	---------	--------	------	----	-1---	------	--	---	-----
Allocasuarina nana	--------	---------	--------	------	----	-1---	------	--	---	-----
Laxmannia gracilis	--------	---------	--------	------	----	-1---	------	--	---	---1-
Cryptostylis subulata	-------1	---------	--------	------	----	---1-	-1----	--	---	-----
Persoonia lanceolata	--------	-1-------	--------	------	-1-1	----1	1-----	-1	1--	----1
Microtis unifolia	--------	---------	--------	------	----	-----	------	--	---	----1
Poranthera ericifolia	--------	---------	-------1	------	----	---1-	1--1--	--	11-	----1
Tricostularia pauciflora	--------	---------	--------	------	-1--	---1-	11-1--	11	1--	----1
Amphipogon strictus	--------	---------	--------	------	----	-1---	------	-1	111	-----
Mirbelia rubiifolia	--------	---------	--------	------	--1-	-1---	------	11	111	1----
Cassytha glabella	--------	---------	--------	1-----	---1	-1--1	-1----	11	111	1----
Selaginella uliginosa	--------	---------	--------	------	---1	-----	------	--	111	-----
Banksia oblongifolia	--------	---------	--1-----	------	----	111-1	-----1	12	113	1----
Ptilanthelium deustum	------1-	---3-----	--1-----	------	-121	-21-2	11--22	12	212	1----
Patersonia sericea	--------	1--11----	--------	------	----	-1--1	--11-1	11	111	----1
Goodenia bellidifolia	------11	---------	--------	------	1-1-	-----	-1----	-1	111	-----
Xanthosia tridentata	------11	-121-----	1-1-1-1-	--1--1	1--1	-1111	-----1	11	111	-----
Cryptandra ericoides	--------	---------	--------	------	----	---1-	------	--	1-1	-----
Thysanotus juncifolius	--------	---------	--------	------	----	---1-	------	-1	111	1----
Leucopogon esquamatus	--------	---------	--1-----	------	-1--	---1-	-1---1	11	111	2----

Drosera peltata	-----1--	--11-----	--------	------	----	--11-	-1--1-	11	111	-1---
Baeckea brevifolia	--------	---------	--------	------	----	-----	------	-1	11-	-----
Burchardia umbellata	--------	---------	--------	------	----	-----	------	11	11-	-----
Sowerbaea juncea	--------	---------	--------	------	----	-----	------	11	11-	-----
Pultenaea elliptica (rf)	--------	---------	--------	------	----	-----	------	13	11-	-----
Blandfordia nobilis	--------	---------	--------	-----1	----	-----	------	11	1-1	-----
Conospermum taxifolium	--------	---------	--------	------	----	-----	------	11	1--	-----
Hibbertia serpyllifolia	--------	---------	1-------	------	----	-----	-----2	22	21-	-----
Schoenus pachylepis	--------	---------	--------	------	----	---1-	------	22	211	-----
Restio gracilis	--------	---------	------2-	------	--1-	--1-1	------	1-	1--	-----
Stackhousia viminea	--------	---------	--------	------	----	-1--1	------	--	1--	-----
Conospermum tenuifolium	--------	---------	--------	------	----	-----	------	--	1--	-----
Xyris juncea	--------	---------	--------	------	----	-----	------	--	1--	-----
Angophora hispida	--------	---------	--------	------	----	--3--	------	33	---	-----
Brachyloma daphnoides	--------	---------	--------	------	----	1----	--1---	11	---	-----
Kunzea capitata	--------	---------	--------	------	----	11-31	------	32	1-2	3----
Lepidosperma neesii	--------	---------	--------	------	--11	11-1-	------	1-	1--	2----
Grevillea parviflora	--------	---------	--------	------	----	-----	------	1-	---	1----
Hypoxis hygrometrica	--------	---------	--------	------	----	-----	------	1-	---	-----
Stylidium lineare	--------	--1------	--------	------	----	---11	------	--	--1	1----
Thelionema caespitosum	--------	---------	--------	------	----	----1	------	--	--1	-----
Sprengelia incarnata	--------	---------	--------	------	----	-----	------	--	--1	-----
Stackhousia nuda	--------	---------	--------	------	----	-----	------	--	--1	-----
Orthoceras strictum	--------	---------	--------	------	----	-----	------	--	--1	-----
Aristida warburgii	--------	---------	--------	------	----	-----	------	--	--1	-----
Dillwynia floribunda	--------	---------	--1-----	------	--2-	1-1--	------	--	--1	1----
Leptocapus tenax	--------	---------	--2---1-	------	----	111--	------	--	312	-----
Lepidosperma squamatum	--------	-3-------	--------	------	1---	-11--	------	--	---	-----
Actinotus helianthi	--------	---------	--------	------	----	--1--	------	--	---	-----
Pseudanthus orientalis	--------	---------	--------	------	----	--1--	------	--	---	-----
Styphelia triflora	--------	---------	--------	------	----	--1--	------	--	---	-----

Baumea acuta	--------	---------	--------	------	----	--1--	------	--	---	-----
Baeckea imbricata	--------	---------	--------	------	----	---32	------	--	---	1----
Restio fastigiata	--------	---------	--------	------	----	---3-	------	--	---	1----
Lepidosperma filiforme	--------	---------	1-2-----	------	----	---22	1--1--	--	---	2----
Banksia ericifolia	------1-	---------	111-1---	---1--	-1--	21243	3----1	--	--1	3---1
Eucalyptus apiculata	--------	---------	--------	------	----	----3	------	--	---	3----
Drosera spathulata	--------	---------	--------	-----1	----	-----	------	--	1--	1----
Allocasuarina distyla	--------	---------	--------	------	----	-----	------	--	---	1----
Leptospermum trinervium (bl)	--------	---------	2-------	-----1	111-	----1	------	11	111	1--1-
Eucalyptus haemastoma	--------	---------	--------	------	----	----1	------	21	-22	-----
Baeckea densifolia	--------	---------	--------	------	----	----1	------	-1	---	-----
Darwinia diminuta	--------	---------	--------	------	----	----1	------	--	---	-----
Micrantheum ericoides	--------	---------	--------	------	----	----1	------	--	---	-----
Lepidosperma viscidum (cg)	--------	---------	--------	------	-1--	--1-1	---1--	--	---	1----
Epacris obtusifolia	--------	---------	--------	------	----	-----	---1--	--	---	1----
Lepidosperma flexuosum	--------	---------	--------	------	----	----1	------	--	---	1----
Olax stricta	--------	---------	--------	------	-1--	----1	---1-1	--	---	1---1
Xanthosia pilosa (dl)	--------	---------	--------	--11--	----	----1	---1--	--	---	1----
Leptospermum squarrosum	--------	---------	--1-----	------	----	----1	------	--	---	11---
Darwinia fascicularis	--------	---------	--------	---1--	----	-----	------	--	---	32-2-
Thelionema umbellatum	--------	---------	--------	------	----	-----	------	--	---	-1-1-
Pterostylis parviflora	--------	---------	--------	------	----	-----	---1--	--	---	-1---
Prasophyllum brevilabre	--------	---------	--------	------	----	-----	------	--	---	-1---
Hypolaena fastigiata	--------	---------	--------	------	-1--	1----	2-----	--	---	---2-
Kunzea ambigua	--------	----1----	--------	-----1	----	-----	------	--	---	-4434
Callitris endlicheri	--------	---------	--------	------	----	-----	------	--	---	---3-
Lepidosperma viscidum (rg)	--------	---------	--------	------	----	-----	------	--	---	122--
Monotoca ledifolia	--------	---------	--------	------	----	-----	------	--	---	--11-
Calytrix tetragona	--------	---------	--------	------	----	-----	------	--	---	--1--
Oxylobium cordifolium	--------	---------	--------	------	----	-----	------	--	---	--1--
Astroloma humifusum	--------	---------	--------	------	----	-----	------	--	---	--1--

Performance of halophytes from semi-arid areas on two saline seepage scalds of the Central Western Slopes of NSW

W.S. Semple and D. Waterhouse

Semple, W.S.[1] *& Waterhouse, D.*[2] *(Soil Conservation Service of NSW,* [1]*PO Box 53 Orange 2800;* [2]*PO Box 445 Cowra 2794). Performance of halophytes from semi-arid areas on two saline seepage scalds of the Central Western Slopes of NSW.* Cunninghamia 3(3): 595–608. Typical halophyte genera from western and coastal NSW are largely absent from saline sites in the central west. Possible reasons for this include climatic and soil differences, relative newness of the central western saline sites and the lack of appropriate dispersal mechanisms. The last mentioned was overcome in this trial by deliberately introducing propagules from semi-arid areas to saline scalds at two sites in the central west. The combined effects of straw mulching and exclosure resulted in the establishment of a number of western species. Two annuals, *Mesembryanthemum nodiflorum* and *Frankenia pulverulenta*, were particularly well adapted. Perennial species of Chenopodiaceae, Frankeniaceae and Zygophyllaceae also established but were slower to colonise. Although propagule availability to both central western sites was similar, there were significant differences in species establishment at the two sites. There were also differences in the occurrence of native/naturalised species between the two sites. Chemical differences between the soils at the two sites were suggested as the reason for this.

Introduction

Recent land degradation mapping* in the Upper Murray–Darling Basin shows that saline sites are widespread on the central west of NSW. 'Seepage scalds', bare eroded areas where a saline watertable is close to or at the surface (Williams & Bullock 1989), are usually present at sites with advanced salinisation. Electrical conductivities (EC_e estimated from $EC_{1:5\ soil:water}$) of 0–5 cm soil samples from a selection of central western scalds ranged from 12 to 56 dSm^{-1} (Hamilton 1972) and in a more recent survey, from 15 to 87 dSm^{-1} (Semple 1993).

According to a Victorian classification of degree of salinisation, many of these sites are 'severely affected' and would be expected to support a sparse cover of halophytes, e.g. *Disphyma crassifolium*+ (Aizoaceae) and species of Chenopodiaceae such as *Sarcocornia*, *Suaeda* or *Halosarcia* (Matters & Bozon 1989). A botanic survey of 21 saline sites in part of the central west of NSW (including the western fall of the Great Dividing Range and extending west to Cowra, Manildra, Dubbo and Dunedoo) found no such halophytes (Semple 1993). Though seepage scalds were largely bare, the most common species present were the grasses, *Critesion marinum*, *Cynodon dactylon*, *Parapholis incurva*, *Polypogon monspeliensis* and the annual forb, *Spergularia marina*, all of which Matters & Bozon (1989) considered typical of 'moderately salted' sites.

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* Unpublished. Prepared at a scale of 1:100 000 for the Upper Macquarie and Lachlan River catchments by the Soil Conservation Service of NSW.

+ Nomenclature in this paper follows Jacobs & Pickard (1981) except where updated by the *Flora of NSW* Vols. 1 (1990), 2 (1991) & Wheeler et al. (1990).

Apart from Poaceae (which contains many salt-tolerant species), Aizoaceae, Frankeniaceae and Chenopodiaceae are major sources of halophytes. None of these families is well represented in the flora of the Central Western Slopes botanic subdivision and even less so on saline sites in the eastern part of the subdivision. Of the 52 species from these families noted as native or naturalised on saline sites (Table 1), 37 are restricted to the Western and/or Far Western Plains botanic divisions and 7 to the Coastal division. Only 6, *Glinus lotoides*, *Tetragonia tetragonioides* (Aizoaceae), *Enchylaena tomentosa*, *Atriplex suberecta*, *A. semibaccata* (Chenopodiaceae) and *Frankenia serpyllifolia* (Frankeniaceae) have a range extending to the Central Western Slopes subdivision. Apart from *A. semibaccata*, none of these species was recorded on or near saline sites in the east of this division by Semple (1993). In a survey of part of the Southern Tablelands, which included saline sites, no plants from these three families were recorded (Kodela & Foster 1990).

The reasons for the lack of coastal, arid and semi-arid forbs and subshrubs on seepage scalds of the central west are unclear, but could include:

- the temperate climate with its frequent frosts and at times, abundant run-on water
- the presence of a continually higher watertable, i.e. 'wet' rather than 'dry' scalds
- the presence of a pre-existing, at least partly adapted, grassy flora on favourable microsites on the scalds
- regular fluctuation in salinity levels — primarily because of rainfall (Logan 1958)
- the generally higher pH and carbonate and/or sulphate contents in western soils (Lawrie 1991) compared to those of the central west.

These potentially adverse effects would primarily affect germination and early establishment. For example, some species are salt sensitive during germination but less so later on and vice versa (Logan 1958). The successful introduction of tubestock of *Atriplex nummularia* (old man saltbush) to seepage scalds of the central west in recent years shows that plants of semi-arid areas can flourish in this environment.

Table 1. Number of taxa from the main dicotyledonous halophyte-containing families recorded as native or naturalised in NSW and the Central Western Slopes (CWS) botanical subdivision.

	No. of taxa recorded in:			**No. of taxa noted to occur in saline habitats***
Family	**NSW#**	**CWS#**	**Eastern CWS saline sites▼**	
Aizoaceae	32	7	0	13
Chenopodiaceae (excluding *Chenopodium*•)	164	24	4	33
Frankeniaceae	11	1	0	6

# From Jacobs & Highet (1990), Jacobs (1990) and Miller (1990).

▼ From Semple (1993).

* Determined from habitat data recorded by the above authors as well as by Cunningham et al. (1981), Matters & Bozon (1989), Clarke (1989) and Runciman & Malcolm (1989). This approach underestimates the number of halophytes, as detailed habitat data was not always available, or was of the form 'occurs in a wide range of habitats'. Also, as many soils of the western plains are naturally saline, e.g. scalds and desert loams (Lawrie 1991), salinity would not warrant particular mention in a habitat description.

• A ubiquitous genus in NSW with no noted halophytes.

However, to the authors' knowledge, this species has not been established from seed, nor has recruitment occurred, on scalds in this region.

A likely reason for the absence of halophytes from more remote botanical subdivisions is the lack of opportunity. This involves changes to the environment, or 'disturbance' (Amor & Piggin 1977), and availability of seed, which depends on dispersal mechanisms, seed longevity and time. It is not known when salinisation first became evident in the central west, but it presumably followed a similar pattern to that reported by Wagner (1957 p.33) in the Goulburn area: 'The condition [salt accumulation and concentration], although previously present to a small extent, first became manifest to a serious degree in this district following the unusually wet seasons of 1950–51–52.' At least one saline site near Manildra has been known since the 1920s (B. Wild, pers. comm.).

Saline habitats are not continuous in space in either the Coast or Western Plains divisions. If disturbance (salinisation) is a geologically recent phenomenon, it is not surprising that the variety of halophytes in the central west is low. The opportunity for seed dispersal by vehicles (e.g. Wace 1977) is low as saline sites are localised and visited mainly by farm vehicles, which would be unlikely to have travelled to other divisions. Similarly, dispersal by domestic livestock also would be unlikely due to the general lack of stock movement (apart from in transit) between the central west and either the coast or western NSW.

The aim of the trial described below was to artificially overcome dispersal problems and deliberately introduce propagules of plant material from western NSW to severely salinised sites in the central west.

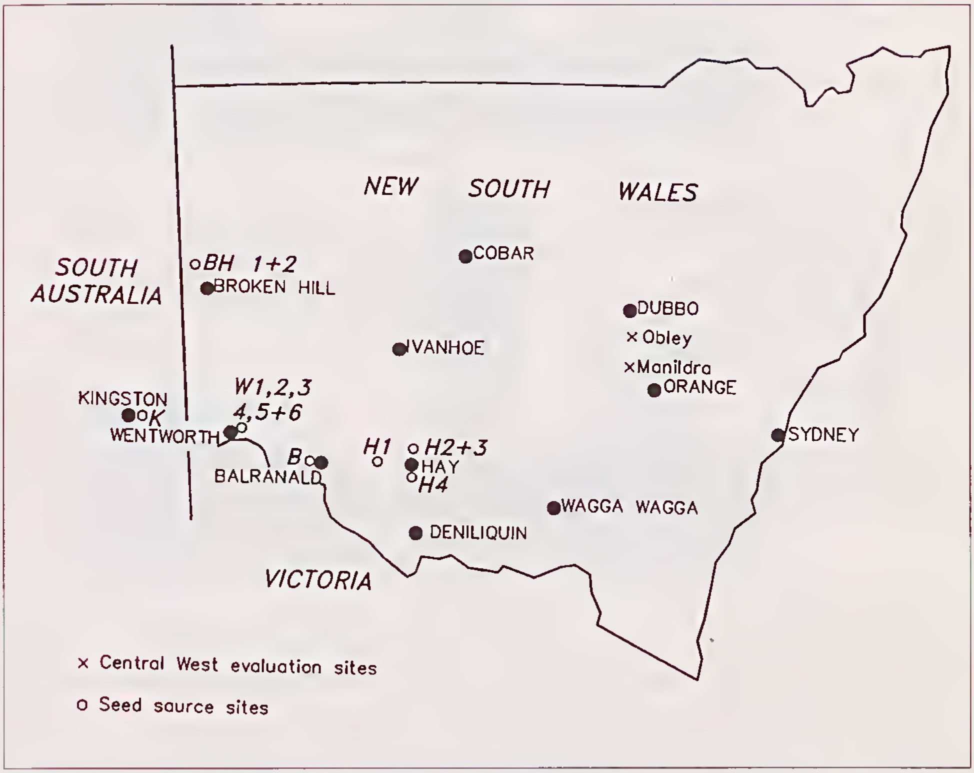

Figure 1. Location of experimental sites and sources of western plant material.

Methods

Several sites were examined and two were selected based on accessibility, apparent uniformity of unvegetated scald surface and consent/interest of the landowner. Site descriptions are provided in Table 2, locations in Figure 1 and rainfall data for Dubbo (40 km north of the Obley site) and Manildra (10 km east of the Manildra site) in Figure 2.

Introduced plant material did not generally consist of specific seed collections. Instead, litter and soil surface 'scrapings' were collected from 13 western NSW sites

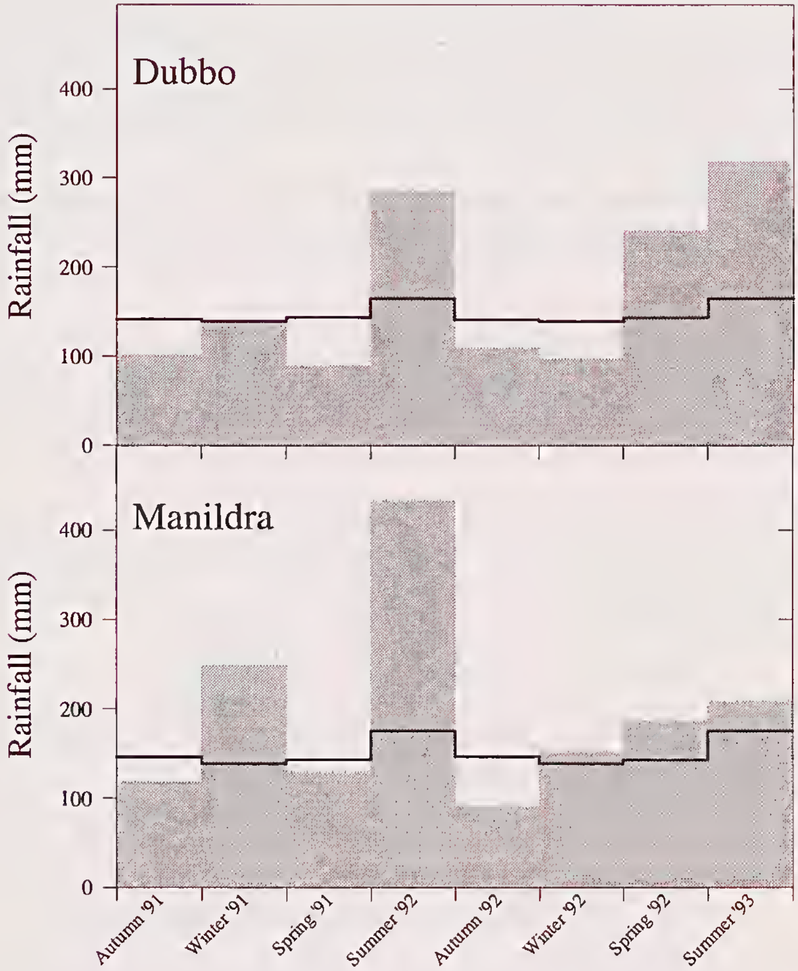

Figure 2. Comparison of autumn 1991 to summer 1993 rainfall and the long-term seasonal average (—) recorded at Dubbo and Manildra.

and one South Australian site (Figure 1) by the authors and other Soil Conservation Service staff during the summer of 1990–91. This procedure meant that the seed composition of the sample was largely unknown. Apparent salinity of the source sites was rated between 'nil' (i.e. naturally low salinity) to 'very saline'.

In addition to this material, seeds or fruits of five known salt-tolerant species and three selections of presumed tolerators were also sown (Table 3).

Trial design consisted of a randomised complete block of 20 (Manildra) and 24 (Obley) 0.25 x 0.25 m plots replicated three times. Each litter sample was split into subsamples (of about 200g, depending on amount of material available) and spread evenly on each of the three replicate plots. All plots were sprayed with a residual insecticide (permethrin at 2.5 g/L a.i.) to stop seed being taken by ants. Cereal straw, which earlier studies (e.g. Wagner 1957, Logan 1958, Hamilton 1972) had shown to be effective in promoting germination and establishment on saline sites, was then applied and held down with netting. Treatments and application rates are listed in Table 3.

The Manildra plots were surface-sown and herbivores were excluded with rabbit-proof netting on 27 March 1991, and the Obley plots received the same treatment on 19 April 1991. Sites were visited at regular intervals spanning four growing seasons (2 x autumn–winter and 2 x spring–summer) to record species present in each plot and on the scald within the exclosure. Known undesirable species, e.g. *Xanthium spinosum*, were recorded and later removed.

Table 2. **Descriptions of experimental sites**

Obley:	20 km north of Obley; adjacent to Paddy's Creek.
Elevation:	350 m.
Topography:	Footslope with saline seepages.
Soil:	Eroded duplex soil with lag gravel, rills, shallow gullies, scalds and hummocks of remnant topsoil. Localised organic (black) staining and on the upper slopes outcrops of calcrete. Within the exclosure the scald's surface is 'puffy' when dry.
Vegetation:	Scattered *Eucalyptus microcarpa* and clumps of *Allocasuarina leuhmannii* with an under storey dominated by *Stipa scabra, Danthonia spp.* and annuals. Scalds support very scattered *Cynodon dactylon, Critesion marinum, Parapholis incurva* and *Spergularia marina*.
Age of site:	The landowner reported that the site has been bare as long as he and his late father could remember.
Manildra:	10 km west of Manildra; adjacent to Manildra Creek.
Elevation:	490 m.
Topography:	Footslope with saline seepages.
Soil:	Eroded duplex soil with rills, shallow gullies, scalds and very low hummocks of remnant topsoil. Localised lag gravel.
Vegetation:	Treeless with scattered *Eucalyptus microcarpa* on the margins. Annual grassland with species of *Lolium, Bromus, Critesion* and *Trifolium*. Scalds support scattered *Parapholis incurva, Critesion marinum, Cynodon dactylon* and *Polypogon monspeliensis*.
Age of site:	The paddock containing the site has been known as 'Salt paddock' for as long as a nearby landholder could remember (c. 60 yrs).

As an indicator of species adaptability to each site, two measures were employed:

- The frequency of occurrence of a species in all plots. This reflects the combination of both seed initially present and the colonising ability of the seed. Changes in frequency between year 1 and year 2 are further indicators of species adaptability to a site.
- The presence of an individual species outside the plots into which it was originally sown, i.e. on bare scald or in mulch-only plots.

Results

During the two-year period, 36 vascular plant species were recorded in the Obley exclosure and 30 at Manildra — representing a total of 48 species, though some were recorded only once or consistently in only one plot. Many of these (20/36 at Obley and 14/30 at Manildra) were already native or naturalised near the experimental site (as well as on the Western Plains).

Species frequencies of occurrence in all plots at each site during years 1 and 2 are shown in Tables 4, 5 and 6. Species which occurred in new habitats (the unmulched scald or unseeded mulch) are shown in Table 7.

The occurrence of some species at one experimental site but not the other prompted a more detailed examination of the soil properties at each site. Analyses of the soils at the experimental sites, together with some Wentworth sites (which represented the largest number of source sites for introduced species) are presented in Table 8.

Discussion

The technique of establishing plants from 'litter' samples placed below straw mulch was successful with many semi-arid species. It was less successful with the known seed introductions. Straw mulch also provided an establishment medium for native/naturalised species, which generally increased in frequency with time. Very few species had the ability to colonise bare scald, despite the lack of grazing.

Annual species

The results indicate that a number of species from semi-arid areas are adapted to saline scalds of the central west — albeit under mulched and ungrazed conditions. As expected in a trial of short duration, annuals were the most common. Of these, large increases in frequency were recorded for *Schismus barbatus, Mesembryanthemum nodiflorum, Frankenia pulverulenta* (Table 6). These species — all introductions to Australia — appear to be of little forage value (Cunningham et al. 1981), and may have weed potential.

Exclosure and mulching also favoured some native/naturalised species (Table 4). Frequency of occurrence of *Critesion marinum and Parapholis incurva* (both naturalised species in NSW) was comparable to that of the most common annuals introduced from farther west.

Many frequently occurring native/naturalised species listed in Table 4 are common on saline sites of the central west and are also found in western NSW. It is likely that many of the plants — particularly in the first year — originated from western 'litter' samples. Of the annuals not commonly associated with saline sites in the central west

Table 3. Treatments and seeding rates at Obley and Manildra

Treatment* and seeding rate	Obley	Manildra
Puccinellia ciliata cv. Menemen 32kg/ha	+	+
Thinopyrum elongatum 64kg/ha	+	+
Chloris truncata, selection 291 40kg/ha	+	+
Chloris truncata, selection 191 40kg/ha	+	+
Enteropogon ramosus, selection 391 40kg/ha	+	+
Trifolium fragiferum cv. Palestine (inoculated) 16kg/ha	+	+
Atriplex nummularia 32kg fruits/ha	+	–
Maireana brevifolia 32kg fruits/ha	+	–
Western NSW/SA litter samples from all sites except BH 1 & 2	+	+
Western NSW litter samples from (Broken Hill) sites BH 1 & 2	+	–
Straw mulch only	+	+
Nil (no mulch or propagules)	+	+

* Except for the 'Nil' treatment, all were mulched with cereal straw at the rate of 8t/ha (Manildra) and 4t/ha (Obley).

Table 4. Frequency of occurrence of native/naturalised species at the experimental sites. Species with < 10% frequency in the second year have been excluded. All are annuals unless indicated by (P).

	Frequency of occurrence (%) in plots at each site			
	Obley		Manildra	
Species	year 1	year 2	year 1	year 2
Bromus molliformis	0	33	0	0
[+] *Chloris truncata* (P)	0	35	0	2
[+] *Critesion marinum*	60	86	35	57
[+] *Cynodon dactylon* (P)	0	4	0	22
[+] *Lolium* sp.	10	19	20	12
[+] *Parapholis incurva*	31	42	88	88
[+] *Polypogon monspeliensis*	0	0	12	10
Sporobolus caroli (P)	0	42	(0)#	(0)#
Vulpia bromoides	1	18	0	0
Arctotheca calendula	0	18	2	0
Sonchus oleraceus	1	0	7	13
[+] *Spergularia marina*	18	36	(0)#	(0)#
Medicago (all species combined)	7	44	8	10
Polygonum aviculare (P)	0	0	5	13

[+] A known tolerator of salinity in temperate areas (Matters & Bozon 1989, Semple 1993).
# Not native/naturalised at this site.

Table 5. Frequency of occurrence of plants from introductions of known seed at the Obley and Manildra sites.

	Frequency (%)in plots in which it was sown				Frequency (%) in all plots			
	Obley		Manildra		Obley		Manildra	
Species	yr 1	yr 2	yr 1	yr 2	yr 1	yr 2	yr 1	yr 2
Puccinellia ciliata	100	100	100	100	24	15	33	60
Thinopyrum elongatum	0	0	0	67	0	0	0	3
# *Chloris truncata* (selections 291 & 191)	0	67	0	17	0	35	0	2
Enteropogon ramosus	0	0	0	0	0	0	0	0
Trifolium fragiferum	0	0	0	0	0	0	0	0
Atriplex nummularia	0	0	–	–	0	0	–	–
Maireana brevifolia	0	0	–	–	0	0	–	–

# This species is native to both sites and western NSW. Plants may have originated from selected, naturally occurring or western seed.
– Not sown at this site.

(those without an ⁺ in Table 4), most were represented by stunted, poorly formed plants.

The introduced species, *Frankenia pulverulenta* and *Mesembryanthemum nodiflorum*, were more successful in establishing on bare scald than most of the native/naturalised annuals (Table 7). They also occurred on the scald outside the exclosures.

Perennial species

Perennial species, either native/naturalised or introduced in 'litter' samples, were well represented at both experimental sites. A number of the introduced species could not be identified until the second year and even then some had not seeded. Due to late or lack of seeding, the colonising ability of some of these species may not be known for some years.

Nine species of introduced perennial plants grew from 'litter' samples. Their capacity to colonise new plots was inhibited by late (year 2) or nil seeding; hence, frequencies were generally low (Table 6). Where an increase between years 1 and 2 occurred, it was likely that the plants were missed or recorded as 'unidentified' in year 1. Two species, *Sclerolaena muricata* var. *villosa* (though native at the Dubbo site) and *Tribulus terrestris*, were considered undesirable introductions, and plants were removed when observed.

Disphyma crassifolium subspecies *clavellatum*, *Osteocarpum acropterum*, *Halosarcia pergranulata*, *Sclerolaena brachyptera*, *S. muricata*, *Frankenia foliosa* and *Nitraria billardieri* comprised most of the introduced perennials. They are known tolerators of salinity or colonisers of dry scalds (Cunningham et al. 1981, Jacobs & Highet 1990, Miller 1990, Jacobs 1990).

Four native/naturalised perennial species were recorded within the exclosures and all increased in frequency between years 1 and 2 (Table 4). The species and their highest frequency of occurrence were *Sporobolus caroli* (42%), *Chloris truncata* (35%), *Cynodon dactylon* (22%) and *Polygonum aviculare* (13%). *P. aviculare* is usually considered a weed, whereas the others produce moderate to high quality forage. *S. caroli* and *C. truncata* are known colonisers of eroded areas (Cunningham et al. 1981). All of the grasses were recorded on bare scald, though the stolons of *C. dactylon* did not extend very far from their origin in a more favourable niche (Table 7).

With the exception of *Puccinellia ciliata*, establishment of perennials from deliberately introduced seed was low (Table 5). *P. ciliata* established in all plots where seed was placed and, following seeding in the first year, it spread to other plots. Its presence in the first year in plots other than those where it was sown indicated some transport of seed at the time of sowing. It had limited ability to colonise bare scald and was present only in a specialised niche, viz. some soil auger holes. *Thinopyrum elongatum* was represented by only a few plants in the second year at Manildra. The fate of the selections of *Chloris truncata* was difficult to determine as the species is native to both sites and also occurs in western NSW. It has been treated as a native/naturalised species in this discussion. *Trifolium fragiferum* did not establish at either site.

Source of semi-arid plant material

In Table 6 an attempt has been made to specify the seed source for the introduced semi-arid species. As would be expected, seed of some species appeared to be present in scrapings from more than one collection site. Wentworth (W) sites, which comprised 43% of all the source sites, accounted for 83% of first observations at Manildra.

All sites appeared to contribute species at Obley, though Wentworth sites were again common (50%).

The high representation of species from the Wentworth sites, prompted an investigation of soil properties at some of these sites. Analyses of soils from two sites (W2 and W4) are compared with the experimental sites in Table 8. Of the four soil analyses, the very high soluble salt concentration (as indicated by high EC), high pH, the high calcium: magnesium ratio of 23:1 (which suggests magnesium deficiency, Eckert 1987), and the high percentage of exchangeable sodium (indicating a strongly sodic soil, Pope & Abbot 1989), sets the Obley soil apart from the others. On soil chemistry alone, the Wentworth sites were more similar to Manildra (where Wentworth species were common) than to the Obley site.

Table 6. Frequency of occurrence and possible source of species introduced in 'litter' samples from semi-arid and arid areas. All are annuals unless indicated by (P).

	Frequency of occurrence (%) in plots at each site				Litter sources (site nos▼) for plants at	
	Obley		Manildra			
Species	**yr 1**	**yr 2**	**yr 1**	**yr 2**	**Obley**	**Manildra+**
POACEAE						
* *Lamarckia aurea*	6	3	0	0	BH1+2	–
* *Schismus barbatus*	8	57	0	0	W4, BH1	–
AIZOACEAE						
Disphyma crassifolium ssp. *clavellatum* (P)	0	13	2	2	H1+3, K, W4+6	W3
* *Mesembryanthemum nodiflorum*	18	88	3	3	W1,2,3,4+5	W2
* *Tetragonia tetragonioides*	0	14	0	0	B, W1, H2 BH1+2	–
ASTERACEAE						
Pogonolepis muelleriana	6	1	0	2	W4+6	W4
Senecio glossanthus	4	29	3	0	W4	W4
BRASSICACEAE						
Menkea australis	1	1	8	7	W4	W2, 3+4
CHENOPODIACEAE						
Atriplex lindleyi	1	3	2	2	B, W6	W4
A. pumilio (P)	3	4	0	0	W4	–
Osteocarpum acropterum var. *deminuta (P)*	0	3	0	0	W6	–
Halosarcia pergranulata (P)	0	0	10	15	–	W2+3
Sclerolaena brachyptera (P)	0	4	0	0	B, H4	–
S. muricata var. *villosa (P)*	0	(1)#	0	2	H2	H2
FRANKENIACEAE						
Frankenia foliosa (P)	0	0	0	7	–	W1+2
* *F. pulverulenta*	0	0	12	68	–	W2, 5+6
ZYGOPHYLLACEAE						
Nitraria billardieri ? (P)	0	0	3	3	–	B
Tribulus terrestris (P)	0	1	2	0	H2	H3
Zygophyllum sp.	0	1	0	0	W4	–

+ Litter samples from BH were not evaluated at Manildra.

▼ Key to sites is shown in Figure 1.

* Not native to Australia (Jacobs & Pickard 1991, Black 1952).

? Tentative identification as plants had not flowered.

# Also native to this site.

Table 7. Occurrence of species in the 2nd year in new habitats following exclosure. All are annuals unless indicated by (P).

Site	Species	Bare scald		
		'Nil' plot	Between treatment blocks	Mulch-only plots
	Native and naturalised species			
Obley	*Bromus molliformis*	+	–	+
	Chloris truncata (P)	+	–	+
	Critesion marinum	+	–	+
	Cynodon dactylon (P)	–	$+^{2}$	–
	Lolium sp.	–	–	+
	Poa annua	–	–	+
	Parapholis incurva	–	–	+
	Sporobolus caroli	–	+	+
	Vulpia bromoides	–	–	+
	Arctotheca calendula	–	–	+
	Spergularia marina	+	–	+
	Medicago spp.	–	–	+
Manildra	*Critesion marinum*	–	$+^{1}$	+
	Cynodon dactylon (P)	–	$+^{2}$	–
	Parapholis incurva	+	+	+
	Introduced species			
Obley	*Puccinellia ciliata* (P)	–	$+^{1}$	–
	Schismus barbatus	+	–	+
	Mesembryanthemum nodiflorum	+	+	+
	Senecio glossanthus	–	–	+
Manildra	*Puccinellia ciliata* (P)	–	$+^{1}$	+
	Frankenia pulverulenta	+	+	+

+ = Present.
– = Absent.

[1] Specialised areas only such as auger holes or adjacent to rocks.

[2] Mainly extension of stolons from more favourable habitats.

Table 8. Analyses of 0–10 cm soil samples from the Obley and Manildra experimental sites and two seed source sites near Wentworth

	Obley	Manildra	Wentworth	
			W2	W4
$\text{pH}_{\text{1:S water}}$	10.9	9.0	7.6	7.9
$\text{pH}_{\text{1:5 0.01M Ca Cl2}}$	10.6	8.8	7.3	7.4
$\text{EC}_{\text{1:5 water}}$ (dSm^{-1})	4.73	1.24	1.26	0.75
EC_{e} estimated# (dSm^{-1})	45	8	29	10
Texture	silt loam	loamy sand	loamy sand	sandy loam
Phosphorus (Bray 2) (ppm)	50	27	38	25
Exchangeable Na percentage*	61.4	2.1	11.0	7.8
Ca	34.8	61.7	76.9	68.9
Mg	1.5	35.5	5.5	14.4
Ca/Mg	36.4	97.2	82.4	83.3

# After Slavich & Petterson (1993).

* As a proportion of exchangeable Na, K, Ca + Mg.

Table 9. Species that were restricted to one or other site (see text for exclusions). Frequency of occurrence in all plots in the second year is an indication of abundance at the site.

Site	Family	Species	Frequency (%)
Obley	Poaceae	*Schismus barbatus*	59
		+*Sporobolus caroli*	42
	Caryophyllaceae	+*Spergularia marina*	36
	Chenopodiaceae	*Atriplex pumilio*	4
		Osteocarpum acropterum var. *deminuta*	3
		Sclerolaena brachyptera	4
	Euphorbiaceae	+*Chamaecyce drummondii*	1
Manildra	Poaceae	*Thinopyrum elongatum*	3
	Chenopodiaceae	*Halosarcia pergranulata*	15
	Fabaceae	+*Melilotus indica*	3
	Frankeniaceae	*Frankenia foliosa*	7
		F. pulverulenta	68

+ = Native/naturalised at the site.

Differences between the Obley and Manildra sites

As indicated above, there were considerable differences in chemical properties between the soils at the experimental sites (Table 8). Physical expression of salinity also varied with puffiness and organic staining present at Obley but not at Manildra (Table 2). In the USA, Obley would be referred to as a 'black alkali' site, where sodium compounds react with soil organic matter to produce a dark-coloured residue which is drawn to the surface in dry periods (Daubenmire 1962).

Differences in the flora at each site were also evident, with some introduced and native/naturalised species being restricted to one site. These species, together with some infrequent (< 10%) native/naturalised species not shown in Table 4, are listed in Table 9.

Excluded from this table are some species that appeared to be restricted to one site in Table 4 but were known to occur outside the exclosure at the other site. Also excluded are species not adequately identified and those species that appeared to originate solely in litter samples from Broken Hill.

The near mutual exclusivity of the naturalised species *Spergularia marina* and *Melilotus indica* on central western saline sites was reported by Semple (1993). Of the semi-arid species, *Schismus barbatus*, *Frankenia pulverulenta*, *F. foliosa* and *Halosarcia pergranulata* were strongly site-specific. *Mesembryanthemum nodiflorum*, though occurring in 3% of plots at Manildra, occurred in 88% of the plots at Obley in the second year.

To be reasonably confident that there is a link between soil chemistry and species occurrence, three assumptions must be made: (1) that introduced species availability at both sites was the same (allowing for the lack of Broken Hill material at Manildra), (2) that seasonal rainfall and groundwater discharge were similar at both sites and (3) that the different mulching rates, 4t/ha at Obley and the higher rate of 8t/ha at Manildra, did not favour one species over another.

The high soluble salt contents at the sites (estimated ECe of 45 dSm^{-1} at Obley and 28 dSm^{-1} at Manildra) were probably sufficient to explain the establishment failure of some species. According to data cited by Taylor (1991), growth of *Trifolium fragiferum* (which failed to establish at either site) stops when EC$_e$ exceeds 10 dSm^{-1}. As growth of *Thinopyrum elongatum* ceases above an EC_e of 31.5 dSm^{-1}, its absence from the Obley site is understandable. However, if soluble salt concentration was the only explanation for species presence/absence, then all species which occurred at the high salinity site, Obley, should also have occurred at Manildra. Table 9 shows that this was not the case. Other soil properties which differed markedly between the Obley and Manildra sites — pH (10.9 *v.* 9.0), exchangeable Na percentage (61.4 *v.* 2.1) and exchangeable Ca/Mg percentage (36.4 *v.* 97.2) — were the most likely reasons.

Conclusions

A number of semi-arid species were able to establish and persist on the two central western saline sites. Though mulching and exclosure may be necessary for establishment, some species were particularly well adapted. *Schismus barbatus, Mesembryanthemum nodiflorum* and *Frankenia pulverulenta*, all annual species, spread beyond the exclosure boundary or at one or other site. Frequency data suggests they were as good, or better, colonisers than the pre-existing annuals.

Perennials such as *Halosarcia pergranulata* and *Frankenia foliosa* were less frequent. As many seeded for the first time in the second year — and some had not seeded at all — their ability to colonise bare scald is as yet unknown.

The reason for the absence of some of these species from the central west is open to conjecture. Lack of transport opportunity and the suspected newness of saline environments appear to be contributory factors. A vegetation survey of saline sites between, say, Manildra and Wentworth, might be instructive.

With the exception of some chenopods, the species introduced from semi-arid areas were of low forage value and some, such as the well adapted annuals, may become weeds. Obviously, any of these species that extend beyond the clinical boundary of a saline site would be an undesirable introduction.

Is there a place for species of low forage value or with other undesirable characteristics on saline sites? Saline scalds of the central west currently support a very sparse cover of low forage quality, mainly non-native species (see Table 2). From a purely reclamation point of view, any species that can extract water, reduce salt accumulation at the surface, and provide ground cover and sites for sediment accumulation, would be better than nothing, provided it did not spread to adjacent non-saline areas. However, as it would be unlikely that even high water-using species would on their own reclaim these sites, it would be difficult to convince landholders of the reclamation value of these species.

Species that were already native/naturalised at the experimental sites were also favoured by exclosure and mulching. The most frequent species were non-native annuals such as *Critesion marinum* and *Parapholis incurva*, which are common on many saline sites in this region. Contrary to expectations, however, these species generally failed to establish on bare scalds in the absence of grazing. *Sporobolus caroli*, a native perennial with useful forage characteristics, and not normally associated with saline sites, was a good coloniser at Obley. It would be a useful addition to any saline site plant material screening program.

Seed of known salt-tolerant species failed to produce mature plants except in the case of *Puccinellia ciliata* (which increased in frequency), *Thinopyrum elongatum* (a few plants of which established at Manildra) and *Chloris truncata* (which increased in frequency but probably with input from local seed). Mulching appeared to have little detrimental effect in the establishment of *Puccinellia ciliata*, contrary to Fleck's (1967) findings. The failure of *Atriplex nummularia* and *Maireana brevifolia* may have been due to seedling death by waterlogging and/or associated pathogens, as establishment of these species is best on mounds (Runciman & Malcolm 1989).

Many of the species performed well at only *one* of the experimental sites. This can be partly explained by the widely different soluble salt concentrations (as measured by electrical conductivity) at the two sites. Preliminary indications are that saline seepage scalds may also be able to be divided into types, e.g. on pH differences, or on whether Na or Ca/Mg dominate the cation exchange complex, and that plant responses on each type are likely to be different. This has implications for current species recommendations for saline site reclamation and for future evaluation trials of plant material for saline sites.

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The native grasslands of the Monaro region: Southern Tablelands of NSW

J.S. Benson

Benson, J.S., (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1994. The native grasslands of the Monaro region: Southern Tablelands of NSW. Cunninghamia *3(3): 609–650.* Eight grassland plant communities were defined from a cluster analysis of vascular plant species recorded in 62 quadrats surveyed between the Australian Capital Territory (35° 11' S) and the Victorian border (36° 53' S) (148° 35'–149° 25' E). 265 taxa were recorded, 189 native and 76 (29%) exotic. Five of the native species are registered as rare or threatened in Australia. Cluster analyses using cover data were deemed superior to presence/absence data. Hybrid, non-metric multi-dimensional scaling revealed that altitude is the main determinant for the distribution of native grassland species and communities.

The native grasslands on the tableland tract of the study area (none of which are protected in conservation reserves) contain a high number (> 35%) of exotic species due to more than a century of grazing and decades of pasture improvement in the surrounding countryside. A number of sites are recommended for protection based on their species diversity, presence of threatened species, or because they are representative of a particular plant community. Many of these are dominated by *Themeda australis*, indicating a lack of continuous grazing. Most of these are located in fenced-off areas such as cemeteries, roadsides or travelling stock reserves (TSRs). Until more research is done on native grassland management it is recommended that practices such as intermittent grazing or occasional burning in autumn should continue. Significant remnants on public land should be managed for grassland conservation.

Introduction

> *It is remarkable that such an extensive tract of country as that known as the Monaro Plains, should naturally be almost destitute of trees and shrubs ... the country is made up of clear undulating plains, with only a few isolated tree-clad localities.* (Cambage 1909)

Recent studies of native grasslands and native grass species in south-eastern Australia have investigated their benefit to grazing or uses in revegetation (Leigh 1991, Roberts 1991, Lodge et al. 1991, Jefferson et al. 1991). Other studies have highlighted the rarity of native grasslands and proposed areas for their conservation (Stuwe 1986, Frawley 1991, McDougall & Kirkpatrick 1993).

In 1991 the World Wide Fund for Nature (WWF) funded surveys of temperate grasslands remnants in four states of south-eastern Australia: New South Wales (including the Australian Capital Territory ACT), Victoria, South Australia and Tasmania. The results of this study are presented in McDougall and Kirkpatrick (1993). As part of that report, Benson and Wyse Jackson (1993) derived a floristic classification of the Monaro native grasslands using TWINSPAN (Hill 1979). Through a combination of iterative (Kirkpatrick 1983) and score-based evaluation methods (Wright 1977), Benson and Wyse Jackson (1993) identified 17 grassland sites of significance for nature conservation.

This paper reclassifies the Monaro data using the flexible UPGMA cluster strategy (PATN package, Belbin 1993) and incorporates additional quadrat data mainly from

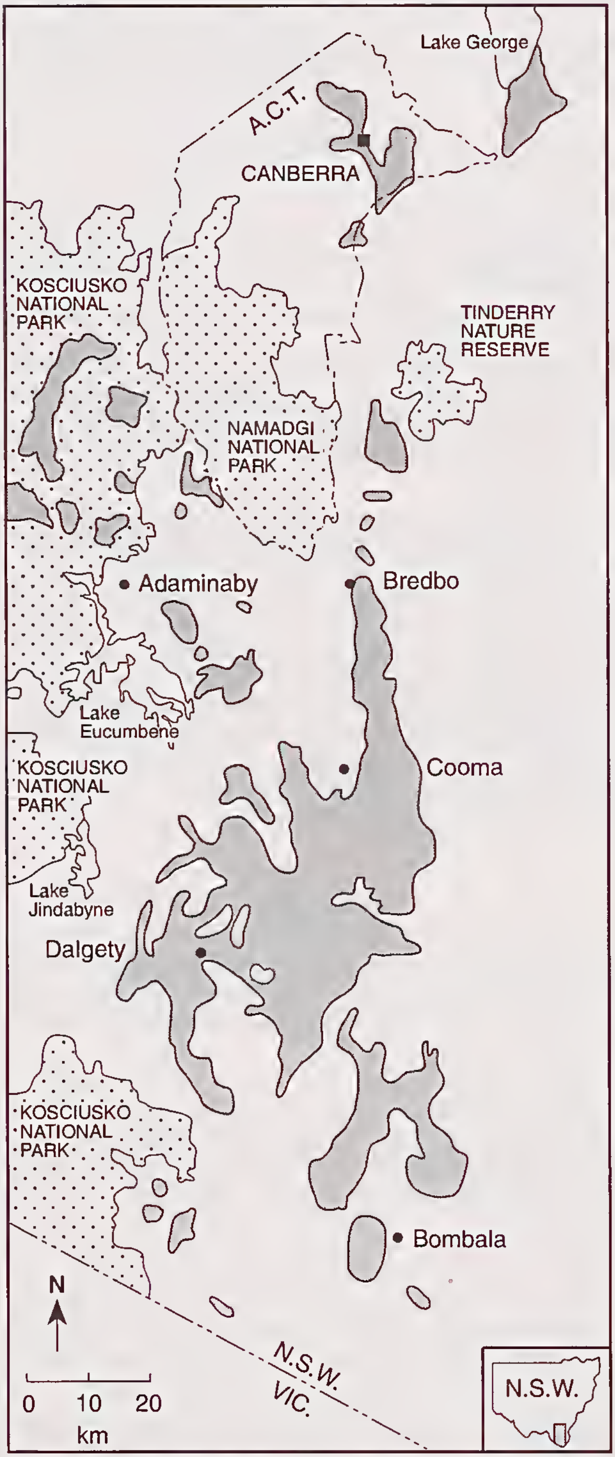

Figure 1. Estimated original extent of native grasslands at the time of European settlement (grey-toned area), excluding subalpine and alpine grasslands above 1500 m. Only a small proportion remains today. Dotted areas are onservation reserves. From Costin (1954) and author's knowledge.

the Montane tract (Costin 1954) on the eastern fringe of Kosciusko National Park. Analysis of the importance of some environmental attributes in determining community distribution was also undertaken. Discussion is provided on the floristic composition, environmental determinants, condition and conservation status of native grasslands and rare grassland species on the Monaro. UPGMA and TWINSPAN are compared regarding their effectiveness in classifying the grassland communities.

For the purposes of this study, the term 'native grassland' refers to areas that contain predominantly native grass and forb plants and are largely devoid of trees and shrubs. In some circumstances a residual understorey of native grass and forb species may exist after the clearing of trees and this may resemble an original native grassland. This survey concentrated on areas that were considered to have been treeless and dominated by herbaceous plants at the time of European settlement.

The study area

The study area is located on the Southern Tablelands of NSW between 35° 11' S and 36° 53' S and 148° 35' and 149° 25' E. It includes most of the tableland (600–950 m a.s.l.) and montane (950–1500 m a.s.l.) climatic provinces of the Monaro region defined by Costin (1954). This region extends from Canberra and Queanbeyan in the north to the Victoria border in the south, bounded in the east by the Kybean Range and in the west by the Snowy Mountains (Figure 1).

Based on the area of grassland mapped in Costin (1954), notes in the early annals of European explorers and the author's field inspections, the pre-European extent of grassland on the Monaro is estimated to have been approximately 250 000 ha.

The elevation of the sites sampled range from 579 m at Queanbeyan to 1380 m at Boggy Plain in Kosciusko National Park. The survey excluded approximately 50 000 ha of grasslands in the alpine and subalpine communities above 1500 m in Kosciusko National Park (McRae 1989) in NSW and subalpine and montane grasslands located in Namadgi National Park in the Australian Capital Territory.

Most of the undulating tableland tract of the region, where the largest area of native grassland once existed, is privately owned and grazed by stock; minor cropping takes place on alluvial flats. Most of the higher altitude or more rugged terrain in the region is located in national parks and state forests.

Climate

On the Monaro, rain falls predominantly in winter. In the south, Dalgety receives only 459 mm annual precipitation. This increases eastwards to Nimmitabel (688 mm) and north-westwards to Adaminaby (701 mm) (Table 1). At the northern end of the study area, Queanbeyan receives an average of 573 mm. Rainfall increases markedly in the mountain ranges to the east and the west. The relative aridity of the tableland section of the Monaro is due to a rainshadow effect which has existed since at least the Miocene (Ride et al. 1989).

Temperatures are cold in winter and mild in summer. The mean temperature of the coldest month ranges from 1.1° C at Adaminaby to 6.1° C at Queanbeyan (Table 1). In summer the mean temperature of the warmest month ranges from 21.1° C at Queanbeyan to 15.6° C at Adaminaby. The coldest temperatures in the study area are experienced in the montane frost hollow valleys in Kosciusko National Park.

Table 1. Climatic attributes of locations on the Monaro (from Costin 1954, Flood 1980)

Location	Latitude	Longitude	Alt (m)	M.C. (°C)	M.H. (°C)	M+9	R (mm)
Queanbeyan	35° 21' S	149° 28' E	579	6.1	21.1	9	573
Cooma	36° 14' S	149° 07' E	811	4.4	18.9	8	476
Nimmitabel	36° 30' S	149° 17' E	1068	2.8	15.8	7	688
Bombala	36° 55' S	149° 14' E	705	5.0	17.8	8	625
Jindabyne	36° 24' S	147° 40' E	945	1.7	16.1	6	547
Dalgety	36° 36' S	148° 50' E	896	3.9	18.3	7	459
Adaminaby	36° 03' S	148° 42' E	1067	1.1	15.6	7	701
Kiandra	35° 52' S	148° 32' E	1395	-0.6	13.3	5	1602

M.C. = mean temperature of coldest month (Celsius)
M.H. = mean temperature of hottest month (Celsius)
M+9 = months with mean temperature > 9^0 Celsius
R (mm) = mean annual rainfall in mm

Geology

The underlying rocks are mainly Palaeozoic sediments which have been folded, faulted and metamorphosed during the formation of the Lachlan Fold Belt which covers a large section of south-eastern Australia (Ollier& Wyborn 1989). Granite intrusions, including the Kosciusko Batholith intruded in the Silurian period. The land surface eroded to a palaeoplain by the Jurassic. This was uplifted, due to undetermined causes, in the Miocene by way of large fault blocks (Ollier & Wyborn 1989). Between 45 and 34 m yrs B.P., during the Eocene, a shield-like volcano erupted causing basalt flows over the southern half of the Monaro. This volcano is thought to have been centered on Brown Mountain (Ollier & Taylor 1988) which is located on the south-eastern fringe of the present Monaro tableland.

The rocks outcropping today vary greatly from the north to the south. Between Canberra and Cooma the main substrates are Silurian and Ordovician volcanics, mudstones, shales and limestones. Some of the larger valleys in the Canberra area, where native grassland was known to exist, are composed of Cainozoic sediments. The elevated region between Cooma and Bombala in the south is mainly composed of Eocene basalt. The western part of the study area in Kosciusko National Park and between Adaminaby and Dalgety is composed of granite and sediments. In the east, the Kybean Range is composed of granite.

The large number of geological types mapped by the Australian Geological Survey in the region have been amalgamated into 12 major groups by Spate (1993) based on their similarity of mineral composition. Soils in the study area are documented in Costin (1954). They include peat and humus podsols in the montane tract; chocolate soils or chernozems on the high basalt plateau between Cooma and Bombala; and red, grey and brown clayey soils (podsols and laterites) derived from volcanic and sedimentary substrates occurring elsewhere on the tableland.

While the drainage in the region tends to follow the north-south orientated bedrock, some rivers have been captured and diverted to the coast with the westwards retreat of the great escarpment (Ollier 1982). Today most drainage is dendritic, except in the south where remnant landforms associated with the Monaro Volcano cause the drainage to be radial.

Some of the higher ground within the study area may have been affected by periglacial activity at the height of the last ice age (18–23 000 yrs B.P.) (A. Costin pers. comm.). The numerous lakes set among the grasslands on the basalt and granite plateau on the southern Monaro are an interesting geomorphological feature (see Benson and Jacobs 1994).

Land-use history and previous botanical studies

A detailed history of Aboriginal occupation in the Monaro is provided by Flood (1980). Due to cold temperatures, and possibly lack of game, it is likely that Aborigines did not favour year-round occupation of the higher parts of the Monaro compared to lower elevations. In autumn, the Aborigines may have gathered and baked seeds of grasses such as *Themeda australis*. However, it seems that seed grinding was not a major part of the economy of the tribes occupying the Monaro. The first European botanist to visit the region, Allan Cunningham, observed Aborigines burning grasslands in Autumn (Havard 1936).

The first European to explore the northern part of the Monaro was Throsby in 1821. Settlement had advanced as far south as Berridale by 1827 (Costin 1954). Both Cunningham and Lhotsky mention the existence of extensive open grasslands in the Goulburn, Lake George and Limestone Plains (Canberra) areas. Lhotsky (1835) estimated that there were 10 000 hectares of grassland on the Limestone Plains. South of the Limestone Plains he describes *Poa* tussock grasslands and gives one of the first descriptions of the Monaro grasslands in the vicinity of Cooma:

> *The scene all around was composed of undulating downs, long projected hills among them, covered with a very few trees.*

The reasons for this absence of trees on the Monaro have long held the interest of botanists. Cambage (1909) suggested the lack of trees could be explained through a combination of low rainfall, cold temperatures, drying summer winds and the structure of the soil. From 1830 onwards the squatters moved in and carved up the country into grazing runs and only a small fraction of the region remained in government ownership. As early as 1840, only 15 years after the first Europeans settled on the Monaro, the explorer Strezlecki expressed concern about the effects that drought, cropping and overgrazing were having on soil erosion (Hancock 1972). Small-scale pasture improvement began in the 1860s. Rabbits proliferated after 1900. Clovers were first sown in the 1920s but pasture improvement accelerated after the second world war, along with the application of superphosphate fertiliser (Hancock 1972).

Cambage (1909 and 1918) provided lists of plant species occurring in the area. A detailed botanical study of the region was undertaken by Costin (1954). This work intuitively classified vegetation to an alliance level and a small scale vegetation map was produced. Costin (1954) recognised two main grassland subformations in the study area; dry tussock grassland dominated by *Stipa scabra* and *Stipa bigeniculata* and wet tussock grassland typified by the presence of *Themeda australis*, *Poa*, *Juncus* and *Carex* species. Pryor (1954) described and mapped the major plant communities occurring in the ACT. A quadrat-based phytosociological study of pastures was carried out by Doing (1972).

Several detailed grassland studies have concentrated on the ACT section of the study area where about 40 grassland remnants have been surveyed (Chan 1980, Hogg 1990, Frawley 1991). The waterplants growing in the lakes on the southern Monaro have been sampled by Benson and Jacobs (1994).

Methods

Compared to their usefulness in vegetation surveys of forest and shrubland, aerial photographs or LANDSAT images proved to be of limited assistance in distinguishing native from modified grasslands on the Monaro. It was therefore decided to select grassland sites through expert advice and by undertaking ground traverses of the countryside. Many sites were selected on the recommendations of the NSW Department of Agriculture, Rural Lands Protection Board, CSIRO and University of Canberra. Additional sites were selected during road traverses on the basis of their apparent natural condition compared to surrounding paddocks. Most of these were located within smaller fenced-off paddocks postulated to have been subject to less continuous grazing. Sampling also aimed to cover the region's main rock and soil types, a range of altitudes and various landform positions (flat, slope, ridge). This meant that some poorer quality sites were recorded to fulfill this aim (for example, drainage lines or flats dominated by *Poa labillardieri* and exotic species).

Sixty-two grassland sites were sampled by way of 100^2 m quadrats placed within them. Sixty quadrats were sampled between October 1991 and January 1992 — a period that coincided with favourable rainfall and abundant flowering. A further two sites were sampled in February 1993. All plant species within a quadrat were recorded and assigned a cover rating based on a six point cover scale (< 1%, 1–5%, 6–25%, 26–50%, 51–75%, 76–100%). Physiographic attributes (slope, aspect, altitude, soil texture, geology and drainage), vegetation structure, land tenure and an estimation of degree of disturbance (including percentage of exotic species) were recorded at each site (Table 2). On the advice of Spate (pers. comm.), his 10 geological categories (Spate 1993) present in the study area were reduced to five by amalgamating three volcanic and sediment categories which have similar compositions (the limestone and Cainozoic sediment categories were maintained).

Soil categorisation at each site was based on observations of texture and colour and reference to Costin (1954). The Australian Map Grid (AMG) coordinate was derived by a geographical positioning system device and topographic maps. Plant species nomenclature follows the *Flora of New South Wales* (Harden 1990–1993).

Data analysis

Quadrats and species were classified into groups by way of an agglomerative hierarchical classification using the Kulczynski coefficient dissimilarity measure and applying the flexible unweighted paired group arithmetic averaging (UPGMA) sorting strategy (PATN, Belbin 1993). The benefits of using the Kulczynski coefficient compared to other measures are discussed in Faith, Minchin and Belbin (1987).

Several UPGMA analyses were performed. One analysis incorporated all species including cover ratings in a matrix of 62 sites (objects) and 265 taxa (attributes). Another analysis excluded exotic species but still included cover ratings, resulting in a reduced matrix of 62 x 189 (it was considered that this analysis may assist with the interpretation of any underlying native floristic patterns not clouded by exotic taxa, many of which have been imposed on the landscape through direct pasture seeding, for example *Trifolium* spp). Further analyses, using all species and native species only, excluded cover ratings and included presence/absence data only. The aim was to assess the importance or otherwise of cover rating in the sorting of sites into groups.

A check on sites suspected to be misplaced in the groupings derived by the favoured UPGMA analysis (this excluded exotic species and included cover ratings of native species) was undertaken by examining the five nearest neighbours of those sites that were generated from the ASO file in PATN using the Kulczyski dissimilarity measure.

Two-way tables for the 'all species' and 'native species only' matrices were generated using the 2-Step association measure on species and Kulczynski coefficient on sites (Belbin 1993). These helped to identify common and indicator plants for each UPGMA defined community and enabled a plant list to be compiled showing the frequency of taxa occurring in each plant community.

Hybrid nonmetric multidimensional scaling (NMDS) (Kruskal 1964) was undertaken to ordinate the quadrat data along three vectors (using PATN, Belbin 1993). NMDS is a robust technique to examine compositional dimensions associated with environmental gradients (Minchin 1987).

To help understand the nature of the environmental space being described by these vectors, a number of analyses were carried out. Scatter plots of sites in the ordination space transcribed by the three vectors were made to look for simple relationships. The GSTA (Group Statistics) module of PATN (Belbin 1993) was performed on the environmental attributes geographic position (easting and northing) and altitude, grouped according to the community analysis. The results of these analyses suggested that vector 2 may describe an altitudinal surrogate. Scatter plots were then constructed for sites which were numbered as per their UPGMA classified community (1–8).

Results

Floristic composition

Two hundred and sixty-five vascular plant species (Appendix 1) were recorded from the 62 quadrats. Of these, 189 are native species and 76 (29%) exotic. The most frequent native species recorded were *Poa sieberiana* (58%), *Acaena ovina* (52%), *Themeda australis* (50%), *Leptorhynchos squamatus* (42%), *Asperula conferta* (39%), *Carex inversa* (37%) and *Elymus scaber* (37%). The most frequent exotic species were *Hypochaeris radicata* (69%), *Vulpia myuros* (58%), *Trifolium campestre* (47%), *Trifolium arvense* (44%), *Bromus hordeaceus* (42%) and *Acetosella vulgaris* (39%).

Large numbers of exotic species were found in most communities but the ratio of native to exotic species varied (Table 2). Sites dominated by *Poa labillardieri* (Community 8) on average contained 52% exotic species. In contrast, only 6% of species recorded in the montane sod-tussock grassland (Community 6) were exotic. Community 3, dominated by *Themeda australis*, contained a lower percentage of exotic species (33%) than the other communities located below 1200 m altitude.

Sites with the highest number of native species were located in lightly grazed areas such as Kosciusko National Park, site 336 at Mount Jerrabomberra, Site 411 on the Snowy Plain, site 354 in the Yaouk Valley and the two sites near Adaminaby (352, 357).

Plant community analysis

Eight communities were defined by the favoured UPGMA cluster analysis selected at the 0.8 level of dissimilarity (Figure 2). This analysis excluded exotic species and included cover data for the native species in the matrix. If taken at the 0.74 dissimilarity level the 17 sites in Community 3 would separate into two groups. It was decided that their overall similarities outweigh their differences, although two sub-

Table 2. Attributes of sample sites

Site	East	North	Location	Geol	Soil	Landf.	Alt	Sl	Asp	Tsp	Nsp	Esp (%)	Tenure
336	6996	60832	Mt Jerrabomberra	S/V	Red clay	LS	610	4	280	39	32	7 (18)	Private
348	6902	60997	Navigation Centre	S/V	Red clay	LS	580	8	0	31	16	15 (49)	Navy
350	6981	60822	Poplars	S/V	Red clay	LS	590	2	320	21	12	9 (43)	Private
349	6973	60930	Campbell	S/V	Red clay	LS	600	3	110	29	18	11 (38)	Open space
351	6882	60996	Lake Ginninderra	S/V	Red clay	LS	580	8	280	25	14	11 (44)	Open space
337	6930	60145	Gungarlin	S/V	Loam clay	MS	600	5	120	20	10	10 (50)	ACT Govt.
338	6832	60737	Paddys River	G	Loam clay	MS	690	11	40	22	12	10 (45)	Private
364	6928	60007	2CY Tower	S/V	Loam clay	F	600	0	–	23	13	10 (43)	Private
366	6827	60741	Paddys Road	G	Loam clay	US	710	3	30	30	19	11 (37)	Roadside
368	6893	60927	Aust. Museum	S/V	Loam clay	LS	570	5	160	23	10	13 (56)	Open space
367	6994	60932	Airport Beacon	CS	Loam clay	F	590	1	240	24	17	7 (29)	Airport
345	6819	59867	Slacks Plain	S/V	Red clay	LS	900	2	330	29	16	13 (45)	Roadside
363	7099	59955	Numeralla Cemetery	S/V	Red clay	LS	610	4	280	16	9	7 (44)	Cemetery
355	6962	60063	Bredbo	S/V	Red clay	LS	720	3	90	39	30	9 (23)	Private
358	6958	60094	Bredbo	S/V	Red clay	R	810	3	30	30	20	10 (33)	Private
356	6557	59551	Beloka Cemetery	S/V	Red clay	US	860	4	315	33	20	13 (39)	Cemetery
352	6617	60150	Adaminaby Hill	S/V	Red clay	US	1040	5	120	35	23	12 (34)	Private
354	6640	60356	Yaouk	CS	Red clay	F	1110	0	–	41	32	9 (22)	Private
357	6612	60144	Adaminaby Saleyards	S/V	Red clay	R	1020	3	80	34	22	12 (35)	TSR
361	6533	59872	Round Plain Church	CS	Grey clay	F	1080	2	160	32	18	14(44)	Church
408	7100	59575	Kydra	G	Grey clay	R	1100	5	160	24	16	8 (33)	TSR
353	6946	60717	Royalla	S/V	Rey clay	LS	890	1	280	32	21	11 (34)	Railway
360	6947	60574	Williamsdale	S/V	Grey clay	LS	750	1	90	31	20	11 (35)	Railway
365	6956	60555	Waterholes	S/V	Red clay	MS	770	1	90	21	16	5 (24)	Railway
359	6537	59869	Round Plain	CS	Grey clay	F	1100	1	180	24	15	9 (37)	TSR
420	7064	59207	Black Lake	B	Choc/cher	R	960	3	270	23	17	6 (26)	TSR
362	6828	60812	Kambah	S/V	Grey clay	US	550	10	330	33	24	9 (27)	Cons. Res.
419	6793	59385	Bungarby	B	Choc/cher	R	960	3	270	21	15	6 (29)	Private
339	6846	59476	Avonlake	B	Choc/cher	US	880	4	120	28	19	9 (32)	TSR
340	6920	59746	Bondo	B	Choc/cher	LS	930	4	90	22	14	8 (36)	TSR
342	6861	59768	North Brother	B	Choc/cher	LS	940	3	240	31	16	15 (48)	TSR
343	6986	59750	Rock Flat	B	Choc/cher	LS	890	5	210	29	14	15 (52)	TSR
341	6828	59677	Ravensworth	B	Choc/cher	MS	1010	4	300	23	16	7 (30)	TSR
344	7013	59300	Home Dale	B	Choc/cher	US	900	5	50	23	14	9 (39)	TSR
346	6964	59779	Manaroo	B	Choc/cher	MS	920	8	290	22	14	8 (36)	Private
347	6899	59710	South Brother	B	Choc/cher	MS	1100	7	90	9	3	6 (66)	Private
369	6604	59670	Birkenhead	G	Sandy clay	R	940	3	320	23	16	7 (30)	Private
372	6791	59169	Quidong	L	Loamy clay	F	630	3	250	24	15	9 (37)	Private
370	6801	59156	Quidong	L	Loamy clay	US	700	9	220	31	21	10 (32)	Private
374	6636	59583	Dalgety	g	Sandy clay	US	760	6	210	18	11	7 (39)	TSR
376	6669	59621	Wyreela	G	Sandy clay	US	800	4	100	20	12	8 (40)	Private
377	6965	60853	Symonston	S/V	Grey clay	F	580	0	–	22	8	14 (63)	Private
371	6964	59252	Bukalong	S/V	Sandy Clay	R	820	2	50	23	14	9 (39)	Roadside
375	6714	59582	Black Range	S	Sandy clay	R	820	0	–	22	12	10 (45)	Roadside
378	6821	59503	Timbury Range	G	Sandy clay	R	940	4	290	13	5	8 (62)	Private
373	6823	59533	Maffra Church	G	Sandy clay	R	930	0	–	18	11	7 (39)	Church

409	6496	60584	Coolamine	L	Humus podsol	F	1260	4	90	26	26	0 (0)	NP
410	6452	60601	Long Plain	S/V	Humus podsol	F	1360	1	150	32	30	2 (6)	NP
418	6489	60290	Nungar Plain	S/V	Humus podsol	F	1340	3	180	26	24	2 (8)	NP
413	6399	60485	Long Plain	S/V	Humus podsol	F	1320	1	30	29	27	2 (7)	NP
411	6403	59933	Snowy Plain	G	Humus podsol	F	1340	2	150	34	32	2 (6)	Private
417	6391	59947	Davies Hut	G	Humus podsol	F	1320	0	–	22	21	1 (5)	NP
416	6398	59862	Botheram Plain	G	Humus podsol	F	1300	0	–	30	26	4 (13)	NP
412	6435	60294	Boggy Plain	G	Humus podsol	F	1380	2	340	32	28	4 (12)	NP
415	6392	59947	Snowy Plain	G	Humus podsol	F	1370	1	0	31	27	4 (13)	Private
414	6521	60364	Gulf Plain	S/V	Humus podsol	F	1240	3	70	28	25	3 (11)	NP
402	6987	59699	Rock Flat Creek	B	Black cher	C	930	2	330	13	6	7 (54)	Private
405	6670	59621	Wyreela	G	Humus loam	C	800	6	120	20	9	11 (55)	Private
403	6998	59975	Spring Bush	S/V	Loamy clay	C	740	2	80	7	4	3 (43)	Private
407	6681	60057	Caddigat Creek	S/V	Humus loam	C	1160	0	–	16	8	8 (50)	Private
404	7172	59727	Kybean River	G	Humus loam	C	1020	0	–	13	5	8 (62)	Private
406	6840	60168	Joes Swamp	G	Humus loam	C	1300	2	90	21	11	10 (48)	Private

Notes.

Full Australian Map Grid (AMG) references are given. **Alt** = altitude; **Sl** = slope in degrees from horizontal; **Asp** = aspect; **Tsp** = total no. species; **Nsp** = no. native species; **Esp** (%) = no. exotic species (percentage of total). **Geol** = Geology (from Spate (1993): S/V = Palaeozoic sediments or volcanics; CS = Cainozoic sediments; G = granites; L = limestone; B = basalt). **Soils** are classified from field observations and from Costin 1954. Choc/cher = chocolate or chernozem soils derived from basalt. **Landf. (LF)** = LS: lower slope; MS: mid–slope; US: upper slope; R: ridge; F: flat; C: creek or drainage line.

Site 367 has been transferred from Community 3b (where it was placed in the UPGMA analysis) to Community 2 (see text).

groups (3a and 3b) are recognised based on a number of species exclusive to one or the other (for example *Dodonaea procumbens* only occurs in 3a).

One site, 367, which is dominated by *Themeda australis* and *Poa sieberiana*, was manually transferred from Community 3 to Community 2 in the classification based on an examination of the location of its five nearest neighbours in the analysis, its species composition and its geographical position in the ACT. Two sites in Community 2 (sites 368 and 337) listed site 367 as one of their closely allied sites, yet the two nearest neighbours to site 367, grouped into Community 3, did not have 367 as their nearest neighbour. Site 367 also contains *Eryngium rostratum* with *Juncus filicaulis* recorded as being adjacent to the quadrat. Both of these species are more typical of sites grouped under Community 2 than Community 3.

Relationships of site groupings to site attributes can be seen by examining Table 2, Figure 3 (altitude versus vector 2) and Figure 4 (geographic position map). Table 2 reveals the fidelity that some communities have for geology and soil type and therefore the value of these attributes as predictors of the vegetation. Community 4, for example, is restricted to basalt substrate weathering to deep chocolate or chernozem soils. Alternatively, Community 3 is less predictable by way of these attributes as it is present on a range of substrates and soil types.

Altitude was revealed as a possible explanatory variable by examination of Table 2 along with the GSTA analysis. A significant correlation ($p < 0.001$) was found between altitude and vector 2 using all communities (Figure 3; $r = -0.73$). thus, vector 2 may describe a surrogate for an altitudinal gradient, or at least one in which altitude plays a part (for example moisture).

Some communities also display high geographical fidelity. Figure 4 shows how in both eastings and northings Community 1 is tightly clustered and is geographically discrete (ACT region). Community 2 occupies an equally narrow longitudinal band but extends latitudinally much further. Community 4 also occupies a discrete space (south of Cooma). Community 3 is the most widespread of the communities occupying sites from near Queanbeyan to Bombala. There is significant overlap between communities 6 and 7, however they have been separated by the UPGMA classification, and probably reflect local environmental variation.

UPGMA: all species versus native species only

Including the exotic species in the analysis resulted in three of the 62 sites (sites 347, 357 and 367) changing communities. These site changes were judged to have weakened the classification based on site floristics and geographical position. For example it resulted in a poorer relationship of the two subsections of Community 3 (3a and 3b).

UPGMA: cover rating versus presence/absence

When cover rating for each species were replaced with presence/absence in the UPGMA analysis of native species only, changes occurred in the groupings of sites. Group definition became less defined and the dendrogram generated more groups at the 0.8 level of dissimilarity. Communities 6 and 7 did not change, but eight sites (338, 339, 371, 345, 367, 375, 377 and 402) moved between the other groups. Some of these changes contradicted the classification which used cover data. For example, site 402, which is a species-poor site dominated by *Poa labillardieri*, was placed distant from Community 8 where it clearly belongs and into a group resembling Community 2. Likewise, site 375, which is dominated by *Stipa* grasses, changed from its previous logical grouping with other *Stipa* grass sites and was placed among the *Poa sieberiana* dominated sites that occur on basalt.

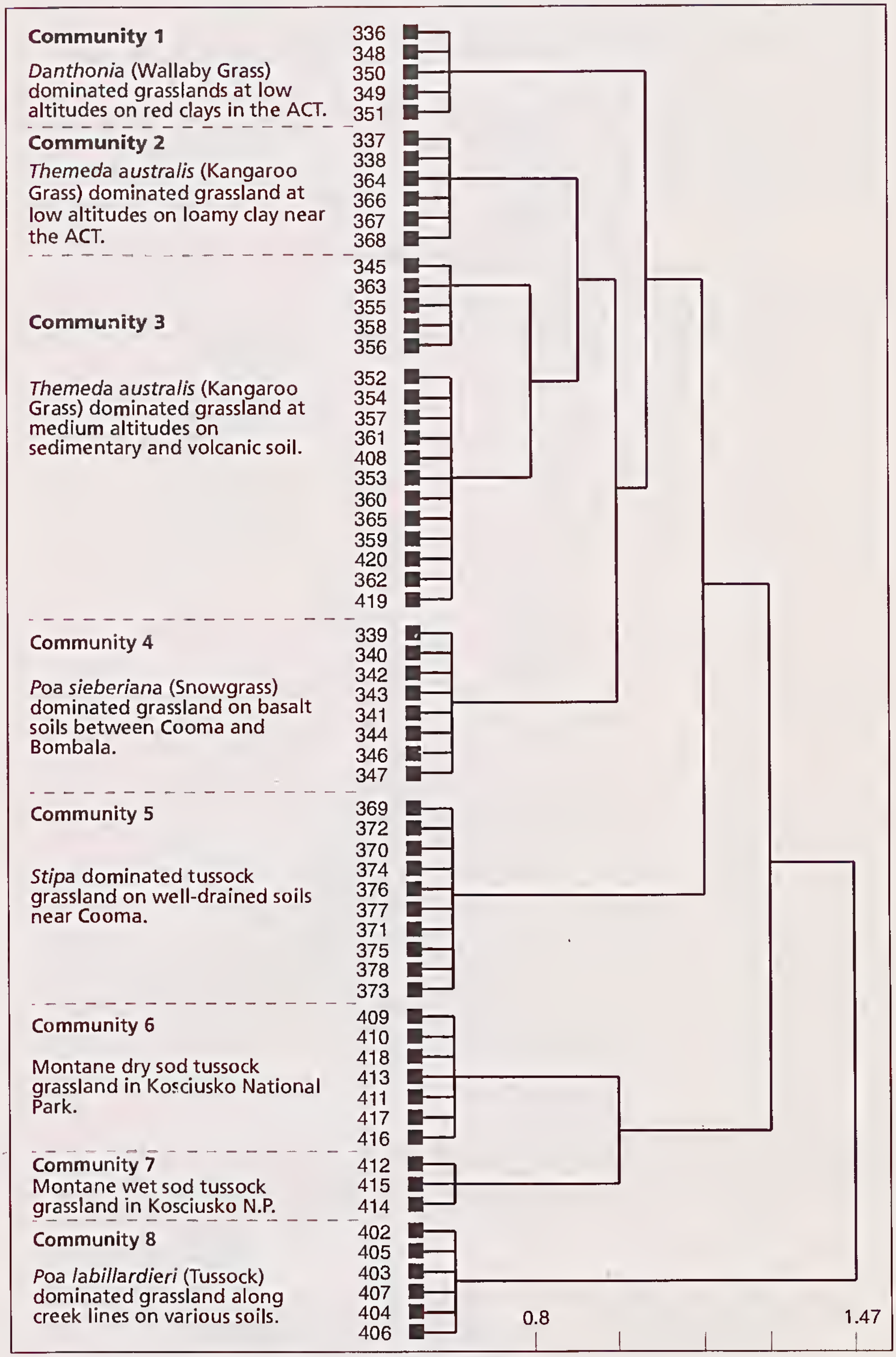
Community 1
Danthonia (Wallaby Grass) dominated grasslands at low altitudes on red clays in the ACT.
336
348
350
349
351
Community 2
Themeda australis (Kangaroo Grass) dominated grassland at low altitudes on loamy clay near the ACT.
337
338
364
366
367
368
Community 3
Themeda australis (Kangaroo Grass) dominated grassland at medium altitudes on sedimentary and volcanic soil.
345
363
355
358
356
352
354
357
361
408
353
360
365
359
420
362
419
Community 4
Poa sieberiana (Snowgrass) dominated grassland on basalt soils between Cooma and Bombala.
339
340
342
343
341
344
346
347
Community 5
Stipa dominated tussock grassland on well-drained soils near Cooma.
369
372
370
374
376
377
371
375
378
373
Community 6
Montane dry sod tussock grassland in Kosciusko National Park.
409
410
418
413
411
417
416
Community 7
Montane wet sod tussock grassland in Kosciusko N.P.
412
415
414
Community 8
Poa labillardieri (Tussock) dominated grassland along creek lines on various soils.
402
405
403
407
404
406
0.8
1.47

Figure 2. Agglomerative classification of sites by their similarity of vascular plant composition selected at the 0.8 disassociation value. This analysis is based on cover ratings for native species in each quadrat and excludes exotic species.

It is possible that the use of cover ratings in the UPGMA analysis may have clouded more subtle species relationships between sites due to their sharing of less abundant species. In most sites, however, only a few species per quadrat were assigned high cover ratings and it was assumed that the combined association values generated between all species and sites in the analysis would do more to dictate the groupings than a few species with high cover ratings. Ratings were used to help with the classification and perennial dominant species are important in this regard. This hypothesis, however, needs more testing.

UPGMA versus TWINSPAN

The classification of the plant communities generated by the agglomerative hierarchical classification UPGMA sorting strategy (Belbin 1993) was considered to be superi-

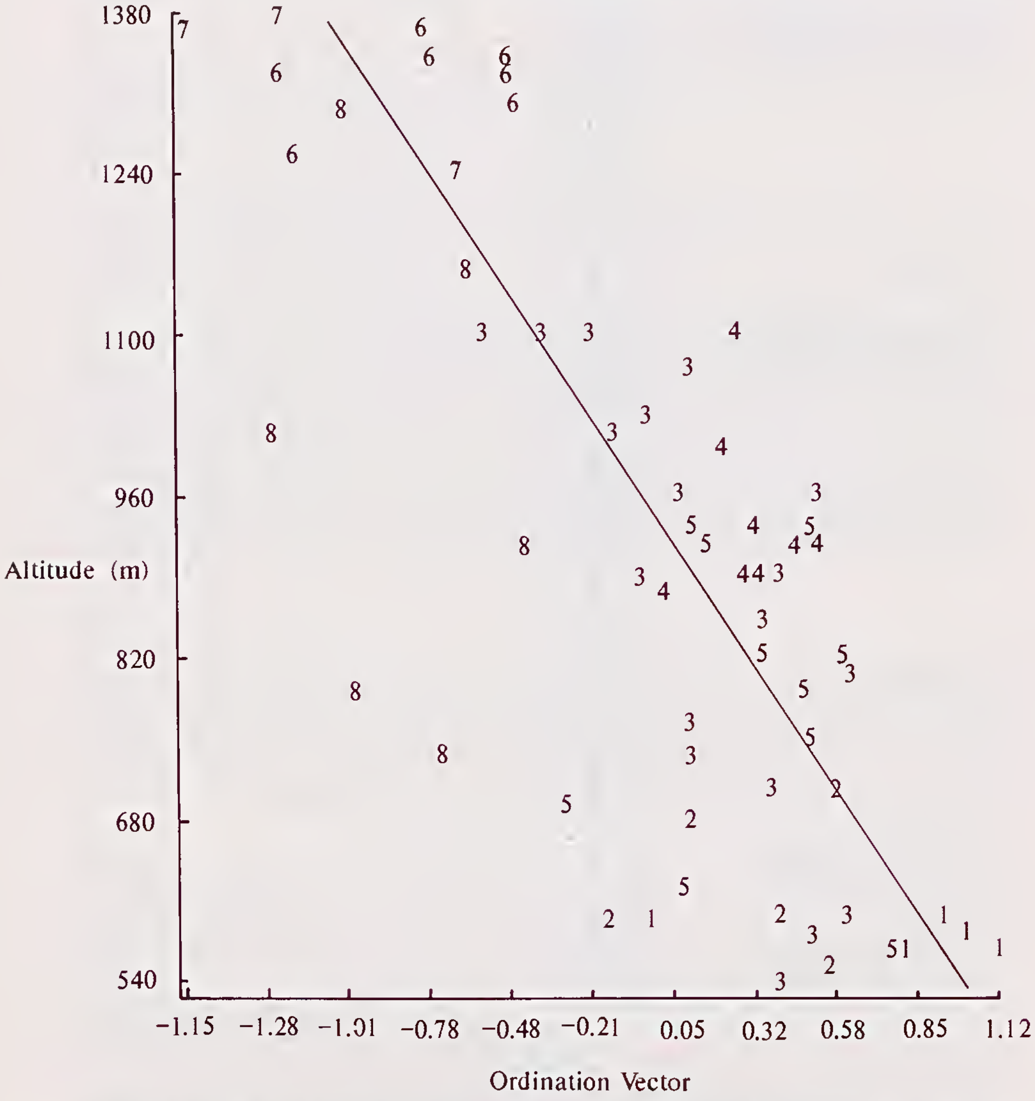

Figure 3. Scatter plot of the altitude and ordination vector 2 values of sites. The site numbers (1–8) reflect their community groupings as defined in the cluster analysis.

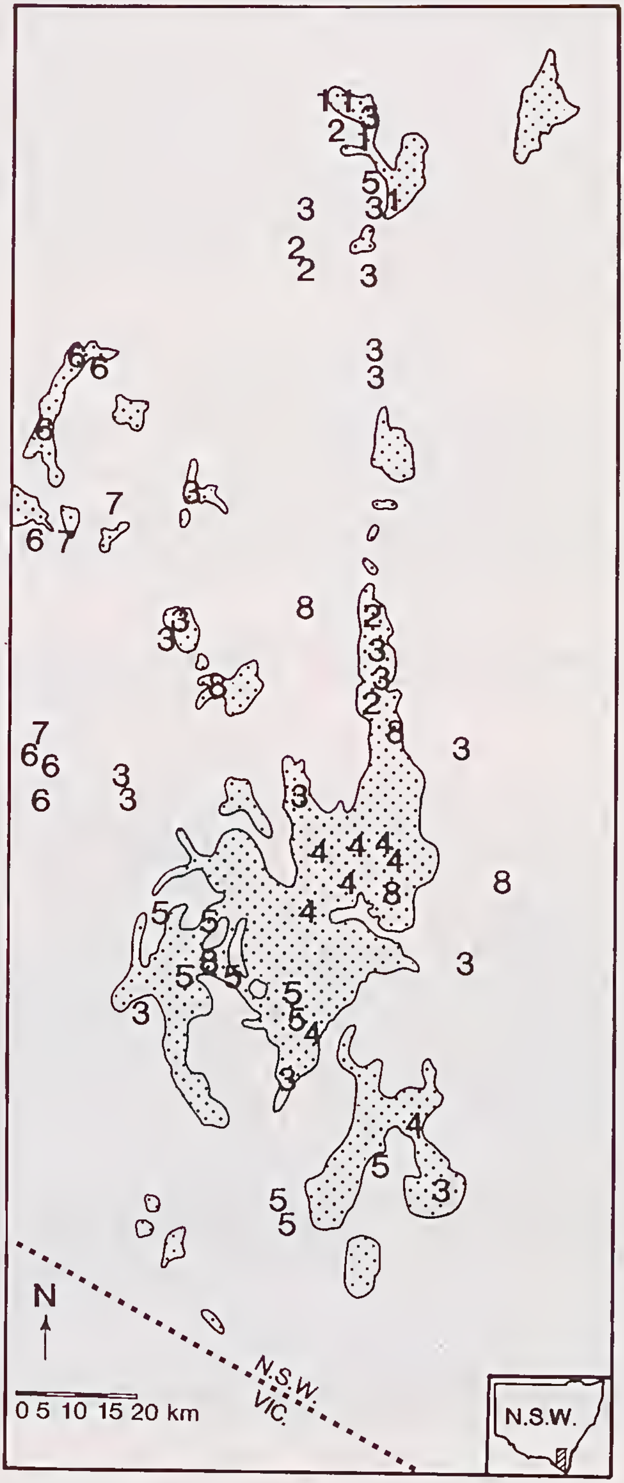

Figure 4. Scatter plot showing the Australian Map Grid locations of the sample sites in the study area. Sites are classified into communities 1–8.

or to that generated by the polythetic hierarchical divisive classification TWINSPAN (Hill 1979) presented in Benson and Wyse Jackson (1993). The UPGMA sorting strategy yielded groups with improved correlation with substrate and geographical location than the TWINSPAN sorting strategy. For example, the two sites within 1 km of each other on the same soils and altitude at Adaminaby (sites 357 and 352) were split into different groups by TWINSPAN but lumped into the same group by all of the UPGMA analyses (native species only, all species, cover ratings, presence/absence). TWINSPAN separated these two sites at an early level in its sorting, principally because site 352 was dominated by *Themeda australis* and site 357 lacked this species because it had been recently grazed.

Grassland communities

The structure and floristics of the eight plant communities selected from the favoured UPGMA analysis are detailed below. The structural classification is based on Walker and Hopkins (1990). Dominant native and common weed species have been selected by examining a two way table generated using cover ratings and all species. Indicator species were also selected from this two way table on the basis of their frequency of occurrence in a community or because they were largely confined to a single community.

• Community 1. *Danthonia* spp.–*Asperula conferta*–*Bothriochloa macra* low grassland on the northern Monaro

No. sample sites: 5

Structure: Mid-dense, low tussock grassland.

Mean no. native spp. per site: 18

Mean no. exotic spp. per site: 11 (38%)

Dominant native species: *Danthonia carphoides, Danthonia auriculata, Asperula conferta, Bothriochloa macra, Vittadinia muelleri, Chrysocephalum apiculatum, Goodenia pinnatifida.*

Indicator native species: *Danthonia carphoides, Danthonia auriculata, Aristida ramosa, Triptilodiscus pygmaeus, Goodenia pinnatifida, Pterostylis mutica.*

Common exotic species: *Vulpia myuros, Bromus hordeaceus, Plantago lanceolata, Parentucellia latifolia, Moenchia erecta, Hypochaeris radicata, Trifolium campestre, Aira elegantissima.*

Landform, geology and soils: Occupies the lower slopes on the margins of valleys composed of paleaozoic sediments and volcanics which weather to form red clay soil.

Distribution: Confined to the ACT and Queanbeyan districts on the northern Monaro. This area contains the lowest elevations and warmest temperatures in the study area; altitude range 580–610 m.

Condition: With the exception of site 336 at Mount Jerrabomberra, this community has a high number of weeds but areas subject to mowing at a height of 10 cm or higher appear to contain healthy stands of *Danthonia* and other native species.

Threats and conservation status: The main threat is urban expansion and the small size of the remnants. No sites are currently protected in reserves.

Key sites for conservation: Site 336, Mount Jerrabomberra, contains one of the largest remaining populations of the endangered plant, *Rutidosis leptorhynchoides*. Site 348, Navy Navigation Centre Belconnen, contains the largest *Danthonia carphoides* dominated remnant sampled in the survey. The site is important as a habitat for a large population of an endangered moth, *Synemon plana*, which feeds on the roots of *Danthonia carphoides* (Edwards 1989).

• Community 2. *Themeda australis*–*Juncus filiformis* grassland of the ACT

No. sample sites: 6 (including site 367)

Structure: Mid–dense, mid–high tussock grassland.

Mean no. native spp. per site 13

Mean no. exotic spp. per site 11 (46%)

Dominant native species: *Themeda australis, Juncus filiformis, Rumex brownii, Eryngium rostratum, Carex inversa.*

Indicator native species: *Themeda australis*, *Juncus filiformis*, *Drosera peltata*.

Exotic species: *Acetosella vulgaris*, *Hypochaeris radicata*, *Bromus hordeaceus*, *Vulpia myuros*, *Cirsium vulgare*, *Aira elegantissma*, *Briza minor*, *Moenchia erecta*, *Plantago lanceolata*.

Landform, geology and soils: Occurs on gentle slopes or flats on either granite or sediments/ volcanics substrate forming loamy clay soils. Sites are often moist indicated by the prevalence of *Juncus filiformis*.

Distribution: Low elevation section of the tableland in the ACT.

Condition: High weed content, low native species diversity.

Threats and conservation status: Most sites are threatened by urban development and further weed invasion. Sites 337 and 368 are in ACT urban parkland.

Key sites for conservation: Site 364, 2CY Tower ACT; site 367, Airport Beacon which contains three threatened fauna species (S. Sharp pers. comm.).

- **Community 3. *Themeda australis–Poa sieberiana–Chrysocephalum apiculatum–Acaena ovina* tall grassland** (Figures 5, 6 and 7)

No. sample sites: 17 (excluding site 367).

Structure: Dense, tall tussock grassland.

Mean no. native spp. per site 20

Mean no. exotic spp. per site 9 (33%)

Dominant native species: *Themeda australis*, *Poa sieberiana*, *Chrysocephalum apiculatum*, *Acaena ovina*, *Leptorhynchos squamatus*, *Plantago varia*, *Asperula conferta*, *Danthonia laevis*, *Elymus scaber*, *Carex inversa*.

Indicator native species: This relatively heterogeneous community falls into two subgroups (3a and 3b). Subgroup 3a is distinguished by containing *Dodonaea procumbens*, *Swainsona sericea*, *Pimelea curviflora*, *Vittadinia muelleri*, *Stipa scabra* subsp. *falcata* and *Stipa nodosa*. Subgroup 3b is distinguished by the presence of *Ranunculus lappaceus*, *Geranium retrorsum*, *Lomandra multiflora*, *Senecio quadridentatus*, *Carex inversa*, *Geranium solanderi* and *Leptorhynchos squamatus*.

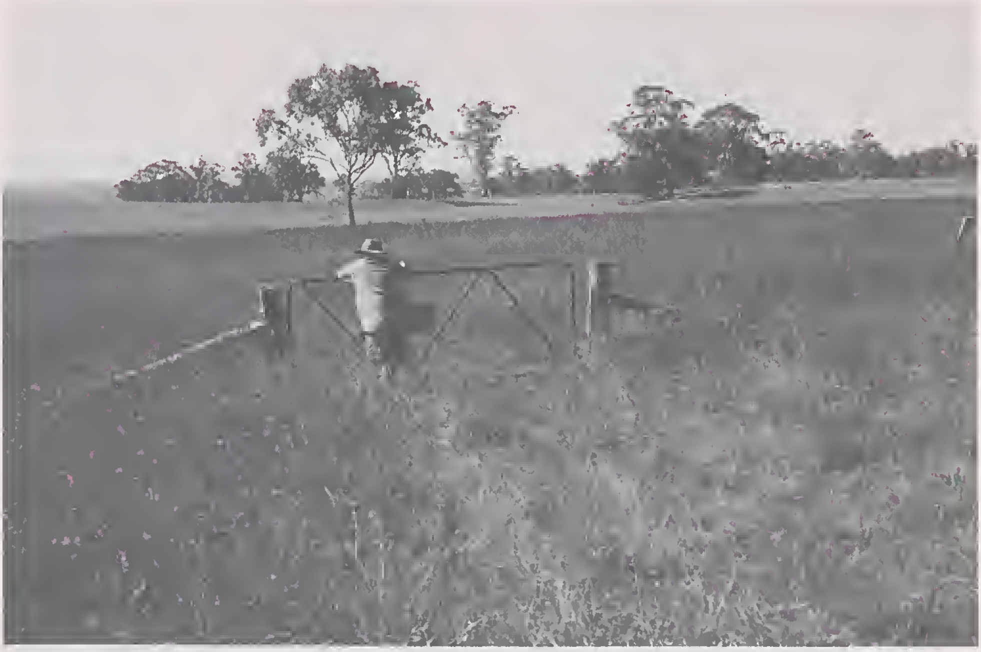

Figure 5. A travelling stock reserve near Black Lake east of Bombala dominated by a summer growth of *Themeda australis*. This species and other palatable plants were found to be most abundant in fenced off and lightly grazed areas such as churches, cemeteries, TSRs and rail easements.

These floristic differences indicate that Community 3a contains species more adapted to well drained sites than Community 3b.

Exotic species: *Trifolium glomeratum*, *Trifolium arvense*, *Trifolium campestre*, *Vulpia myuros*, *Tragopogon dubius*, *Hypochaeris glabra*, *Hypochaeris radicata*, *Cerastium glomeratum*, *Bromus hordeaceous*.

Landform, geology and soils: Community 3a occurs on well drained slopes or ridges on sediments or volcanic substrates forming red clay soils. The two Bredbo sites (355 and 358) are situated on tilted shales with shallow soils. Community 3b occurs in a variety of positions in the landscape, on mixed substrates and different soil types, although grey clay was recorded as the most common soil.

Distribution: Low to high altitudes mainly on the tableland tract. This is the most widespread of the eight communities, ranging from Kambah near Canberra in the north to near Bombala in the south and Adaminaby in the west. It occurs at a range of altitudes (550–1100 m).

Condition: Excluding the montane communities 6 and 7, the sites in this community were deemed to be in good condition. They contained a relatively low percentage of exotic species and a high diversity of native plants. It would appear that sites dominated by *Themeda australis* have been less intensively grazed, at least over recent times.

Threats and conservation status: Most of these sites are fenced off from stock for one reason or another. Some such as TSRs are subject to intermittent grazing, others such as the Beloka and Round Plain cemeteries are subjected to occasional mowing. The main threats are increased grazing pressure and further weed invasion. Site 354 in the Yaouk Valley is threatened by cultivation. None of the grassland areas of this community are protected in conservation reserves. Previously forested grassland containing a similar species composition to this community is located in the Naas and Grassy Creek sections of Namadgi National Park in the ACT (unpublished site data F. Ingwersen pers. comm.).

Key sites for conservation: With the exception of site 345, Slacks Plain, all of these sites are worthy of protection. The most important sites are: sites 355 and 358 at Bredbo that contain populations of the rare *Dodonaea procumbens*; sites 352, 357 and other areas at Adaminaby which contain populations of the rare *Discaria pubescens*; site 354 at Yaouk which contains a high species diversity; sites 353 and 360 along the abandoned Queanbeyan railway line which contain the largest known populations of the endangered *Swainsona recta*.

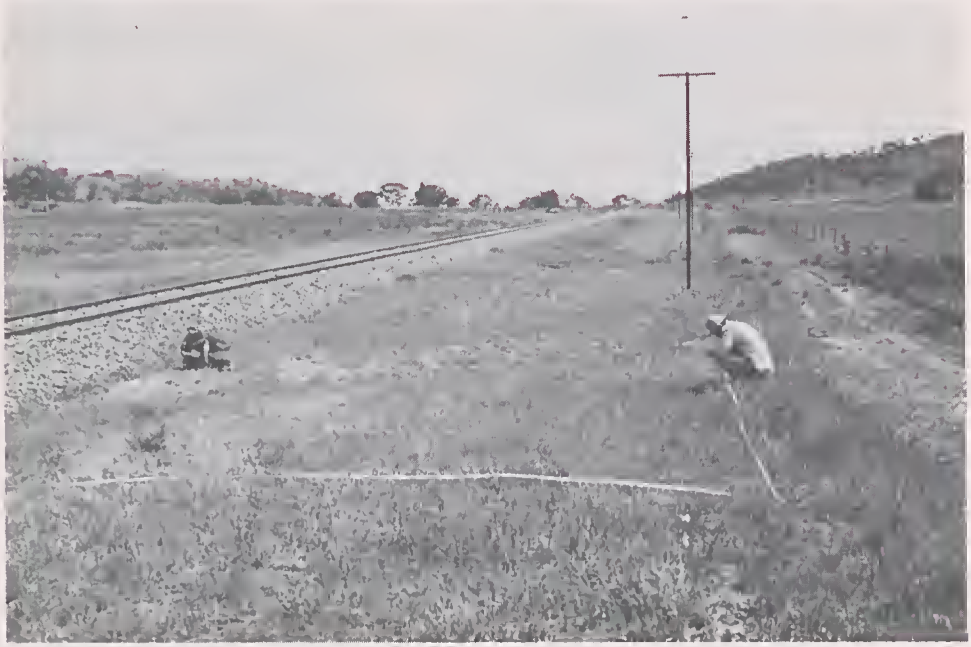

Figure 6. The Queanbeyan–Cooma abandoned railway easement contains patches of *Themeda australis* grassland and the largest known population of the endangered forb *Swainsona recta* (site 353).

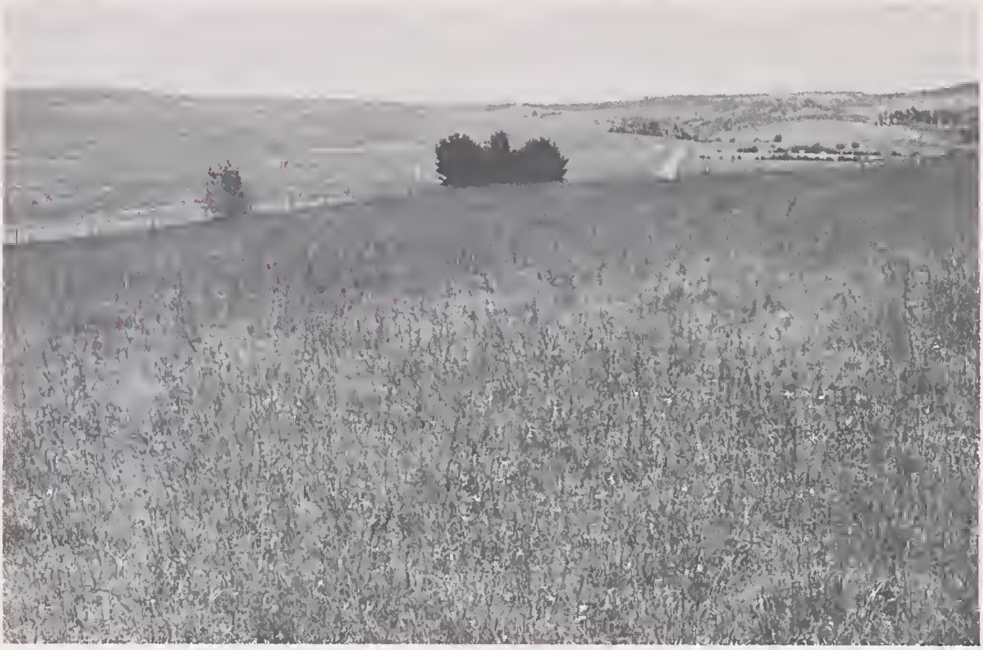

Figure 7. *Themeda australis* growing on private land east of Adaminaby (site 352). Several adjacent TSRs also contain grassland in relatively natural condition.

• **Community 4. *Poa sieberiana–Acaena ovina* grassland on basalt, southern Monaro** (Figure 8)

No. sample sites: 7

Structure: Dense, mid–high tussock grassland.

Mean no. native spp. per site 14

Mean no. exotic spp. per site 10 (42%)

Dominant native species: *Poa sieberiana, Acaena ovina, Asperula conferta, Bothriochloa macra, Danthonia caespitosa, Scleranthus diander, Psoralea tenax, Stipa bigeniculata, Wahlenbergia communis.*

Indicator native species: *Poa sieberiana, Psoralea tenax, Scleranthus diander.*

Exotic species: *Poa bulbosa, Vulpia myuros, Trifolium striatum, Trifolium campestre, Salva verbenacea, Petrorhagia nanteulii, Hypochaeris radicata.*

Landform, geology and soils: Occurs on an undulating plateau composed of basalt which has weathered to form deep, chocolate/chernozem soils.

Distribution: This is the dominant vegetation community on the extensive basalt plateau situated on the high tableland section of the study area between Cooma and Bombala. Maximum elevations extend to 1100 m (montane). Approximately 80 000 hectares of this area is covered with this semi-natural tussock grassland.

Condition: Moderate numbers of native species; all sites with a mixed native/exotic species cover occupying the inter-tussock space.

Threats and conservation status: The region where this community occurs is grazed by sheep and cattle and there has been some improvement of pasture — particularly by sowing clover species. The quadrat data suggest that TSRs have a higher native species richness than private land. Overgrazing of TSRs remains the major threat. No sites are protected in conservation reserves.

Key sites for conservation: Based on floristic composition it is difficult to single out any of the sites for special conservation action. All sites are valuable for conserving representive samples of this community. A number of the TSRs could be protected by reservation or conservation agreement (see Table 3).

• **Community 5. *Stipa scabra* subsp. *falcata–Stipa bigeniculata* grassland** (Figure 9)

No. sample sites: 10

Structure: Mid–dense, tall tussock grassland.

Mean no. native spp. per site: 13

Mean no. exotic spp. per site: 9 (43%)

Dominant native species: *Stipa scabra* subsp. *falcata*, *Stipa bigeniculata*, *Elymus scaber*, *Danthonia caespitosa*, *Enneapogon nigricans*, *Wahlenbergia communis*.

Indicator native species: *Stipa scabra* subsp. *falcata*, *Stipa bigeniculata*, *Stipa blackii*, *Danthonia linkii* subsp. *linkii*.

Exotic species: *Trifolium arvense*, *Vulpia myuros*, *Hypochaeris glabra*, *Hypochaeris radicata*, *Carthamnus lanatus*, *Paronychia brasiliana*, *Aira caryophyllea*.

Landform, geology and soils: Mainly on upper slopes and ridges with well drained, sandy or loamy clay soils derived from granite, limestone and sediments.

Distribution: Occurs on rolling downs below the basalt plateau on the tableland tract in the Dalgety–Berridale region. Outlying sites occur on limestone at Quidong near Dalgety and on the southern outskirts of Canberra.

Condition: Most sites have been heavily grazed and contain moderate numbers of native plants and high numbers of exotics. *Themeda australis* may have been more common before European settlement but is now largely absent.

Threats and conservation status: Pasture improvement and overgrazing threatens the remaining remnants. Site 377 (Symonston) in the ACT is threatened by urban development and is large in area and worthy of protection.

• Community 6. *Poa* spp–*Geranium antrorsum*–*Scleranthus biflorus*–*Leptorhynchos squamatus*–*Ranunculus graniticola* montane, sod tussock grassland (Figure 10)

No. sample sites: 7

Structure: Dense, mid–high, sod-tussock grassland.

Mean no. native spp. per site: 27

Mean no. exotic spp. per site: 2 (6%)

Dominant native species: *Poa sieberiana*, *Poa costiniana*, *Geranium antrorsum*, *Scleranthus biflorus*, *Leptorhynchos squamatus*, *Ranunculus graniticola*, *Acaena ovina*, *Oreomyrrhis argentea*, *Craspedia coolaminica*, *Podolepis robusta*.

Indicator native species: All of the above excluding *Poa sieberiana*, *Leptorhynchos squamatus*,

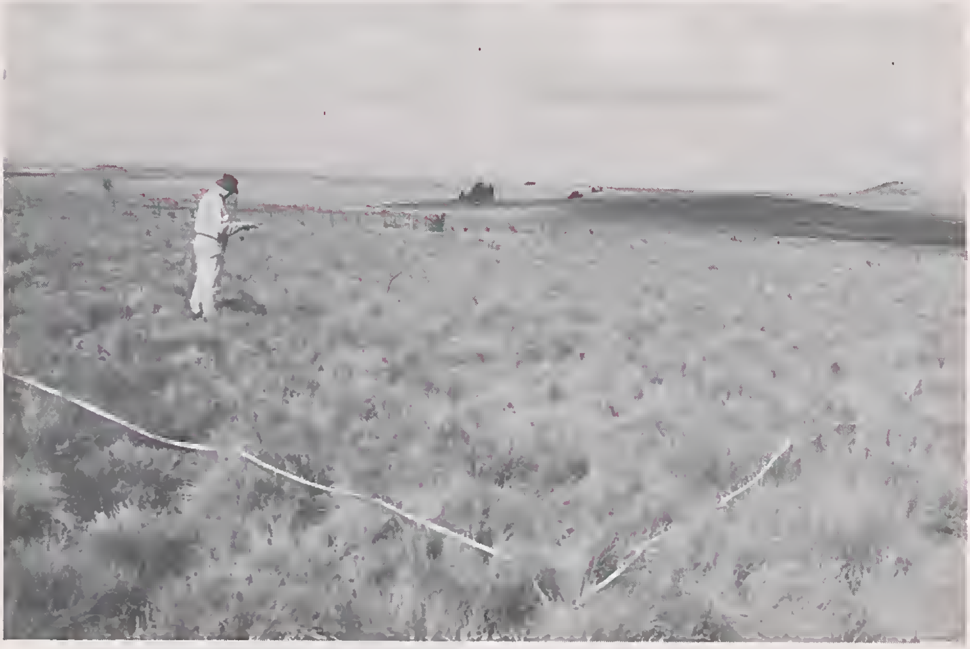

Figure 8. North Brother TSR (site 342). *Poa sieberiana* dominated grassland (Community 4) is confined to the high basalt plateau between Cooma and Bombala.

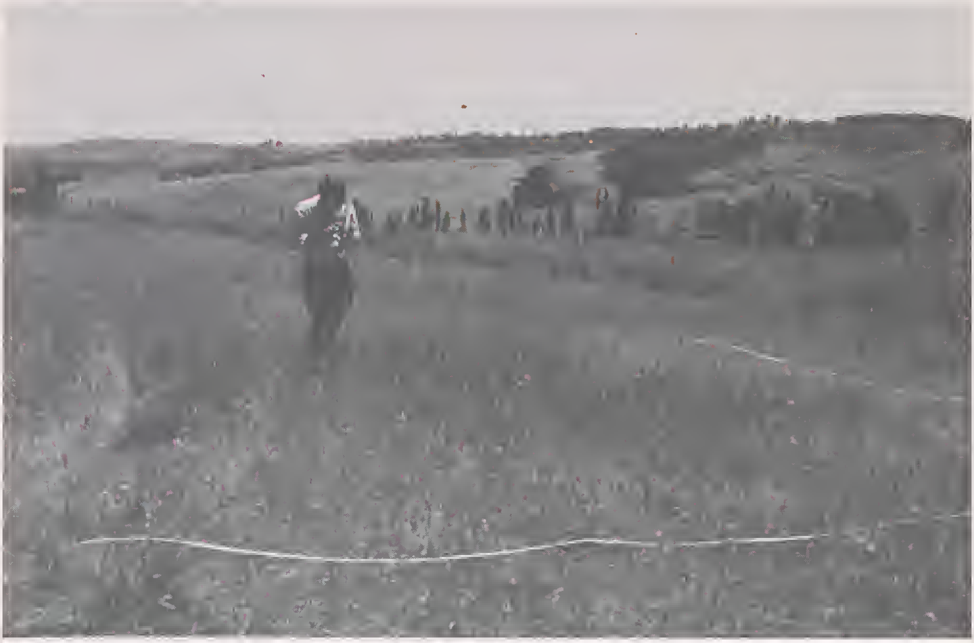

Figure 9. Bukalong roadside (site 371). The *Stipa scabra* subsp *falcata–Stipa bigeniculata* community (Community 5) occurs on better drained and less fertile soils than Community 4. It is likely that *Themeda australis* would have been common in this community before European settlement.

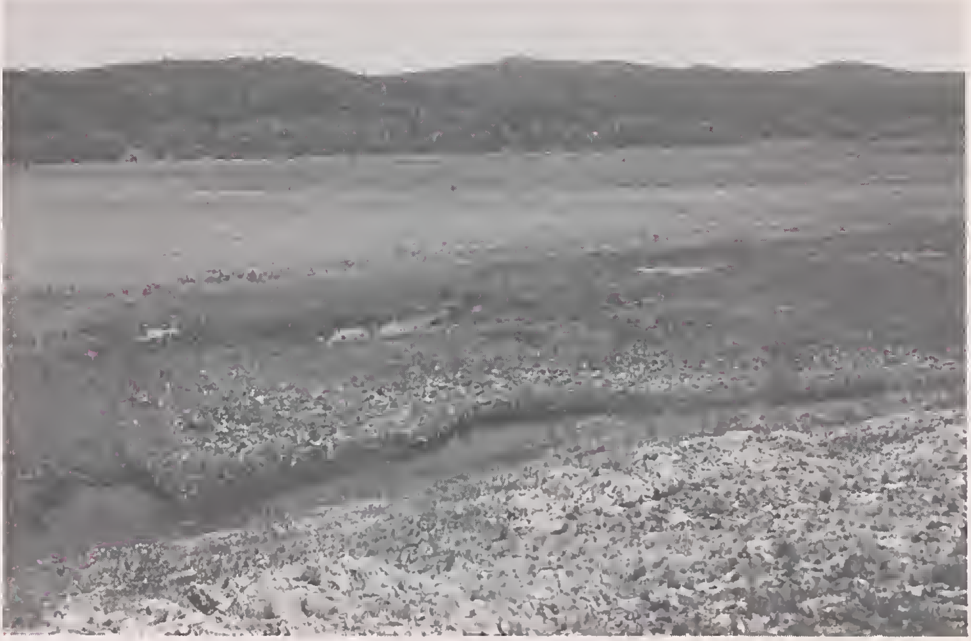

Figure 10. Long Plain (Site 413). The montane/subalpine grasslands (communities 6 and 7) growing in humus soil in frost hollows on the eastern side of Kosciusko National Park contain flora distinct from that present in the grasslands on the tableland tract (see Figure 2).

Acaena ovina. Also, *Microseris lanceolata*, *Wahlenbergia densifolia*, *Danthonia nudiflora*.

Exotic species: Few exotic species were recorded from this community: the most common were *Acetosella vulgaris*, *Hypochaeris radicata*, *Cerastium fontanum* subsp. *trivale*.

Landform, geology and soils: Occurs on valley flats or adjoining gentle slopes affected by cold air drainage; on granite or sedimentary substrates; soils are humus podsolic or peaty, formed under a high rainfall, cold temperature climatic regime.

Distribution: Between 1300–1400 m in the montane, south-western section of the study area.

Condition: Although these valleys were grazed over the last century, there was little pasture improvement and the grasslands are in excellent condition with few exotic species present.

Threats and conservation status: Large areas of this community are represented in Kosciusko National Park.

Key sites for conservation: Site 411 situated on Snowy Plain is outside the Park. In terms of its condition, the whole of the Snowy Plain is worthy of addition to the Park.

• Community 7. *Poa costiniana–Epilobium billardierianum* subsp. *cinereum–Brachycome scapigera–Asperula gunnii* montane, sod-tussock grassland

Sample sites: 3

Structure: Dense, mid–high sod-tussock grassland.

Mean no. native spp. per site: 27

Mean no. exotic spp. per site: 4 (12%)

Dominant native species: *Poa costiniana*, *Epilobium billardierianum* subsp. *cinereum*, *Brachycome scapigera*, *Asperula gunnii*, *Geranium retrorsum*, *Stylidium graminifolium*, *Wahlenbergia multiflora*.

Indicator native species: The above listed species and *Craspedia jamesii*, *Restio australis*, *Cardamine paucijuga*.

Exotic species: *Hypochaeris radicata*, *Acetosella vulgaris*, *Trifolium repens*, *Cerastium fontanum* subsp. *trivale*.

Landform, geology and soils: In wetter areas than Community 6, on valley flats affected by cold air drainage; on humus or peaty soils.

Distribution: Occurs in the same regions as Community 6.

Condition: Contains more weeds than Community 6 but is also in excellent condition.

Threats and conservation status: Well conserved in Kosciusko National Park.

• Community 8. *Poa labillardieri* tall tussock grassland (Figure 11)

No. sample sites: 6

Structure: Dense, very tall tussock grassland.

Mean no. native spp. per site: 7

Mean no. exotic spp. per site: 8 (52%)

Dominant native species: *Poa labillardieri*, *Carex appressa*, *Carex inversa*.

Indicator native species: Species listed above and *Juncus filiformis*, *Haloragis heterophylla*, *Hydrocotyle peduncularis*.

Exotic species: *Poa pratensis*, *Rumex crispus*, *Trifolium repens*, *Trifolium dubium*, *Cirsium vulgare*, *Holcus lanatus*.

Landform, geology and soils: Restricted to drainage lines or river flats on a range of substrates; soils generally loamy.

Distribution: Tableland and montane sections of the study area at a range of altitudes (740–1300 m). Widespread but restricted in extent where it occurs.

Condition: Poor condition; exotic species out number native species.

Threats and conservation status: Nutrient increases due to the application of agricultural fertilisers probably encourages weed invasion. No sites sampled are considered worthy of protection. All are on private land.

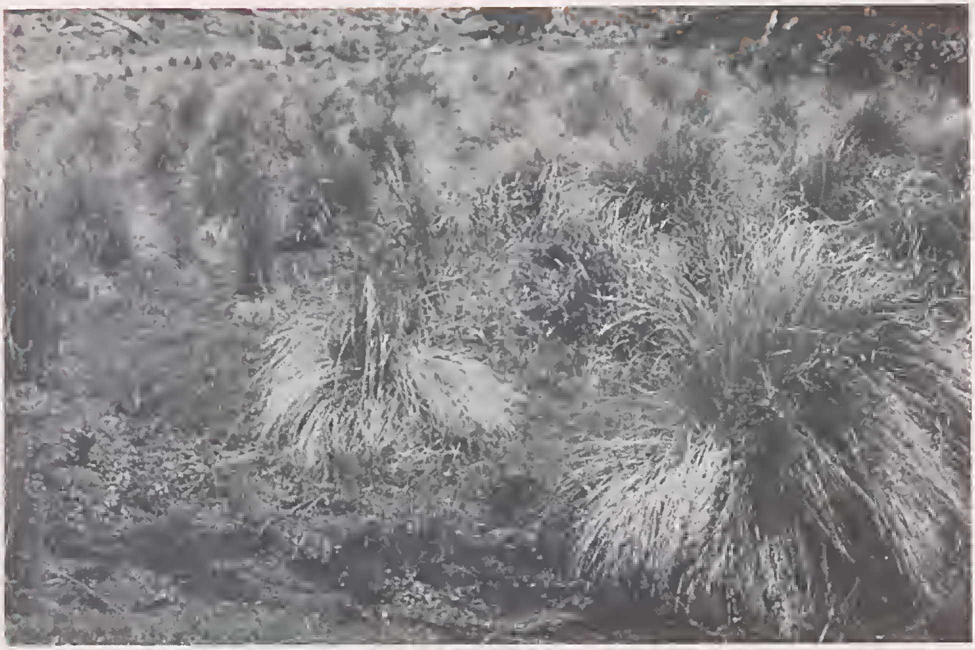

Figure 11. Joes Swamp (site 406). All sites sampled in Community 8 dominated by tall tussocks of *Poa labillarderi* contained a high proportion of exotic plants and low native plant diversity. This community is confined to drainage lines and river flats in the study area.

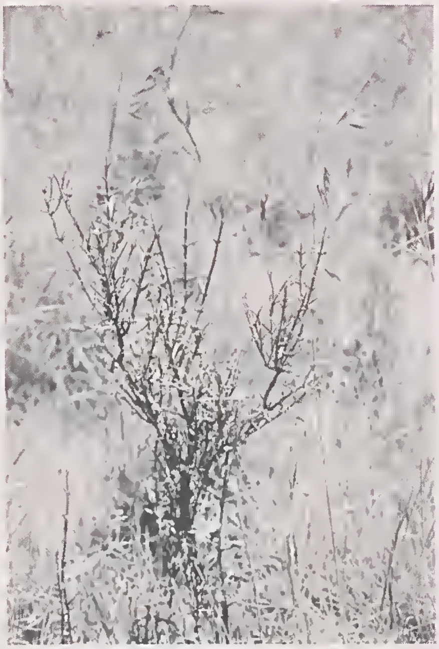

Figure 12. A healthy population of the rare plant *Discaria pubescens* occurs in the lightly grazed Round Plain Uniting Church (site 361) and near Adaminaby (site 352 and adjacent TSRs).

Nationally rare or threatened species

The following five species recorded in the survey are currently listed on ROTAP (Briggs and Leigh in prep.).

- *Swainsona recta* (3ECi): Approximately 1000 plants (J. Briggs pers. comm.) of this species have been counted in *Themeda australis* grassland (Community 3b) along a 22.5 km section of the abandoned Queanbeyan to Cooma railway easement between Tuggeranong in the north and south of Williamsdale in the south (including areas sampled in sites 353 and 360). This represents the largest known population of *Swainsona recta*, which is apparently restricted to grey loamy clay in the study area, as it has not been recorded in similar grassland on red clay further south. A small population also occurs in Canberra and several hundred plants grow near Wellington on the Central Western Slopes of NSW. In October 1993 less than 100 plants were observed in the vicinity of site 353 (J. Briggs pers. comm.). The rail easement population is threatened by grazing by stock, herbivorous invertebrates and by weed invasion. Fire may also play a role in its survival by removing the rank growth of grasses, stimulating resprouting from rootstock or the germination of seed. The railway easement is no longer regularly burnt as it was prior to its closure in 1987 (Zich 1993a). A rare grasshopper, *Keyacris scurra* is also present at this site.
- *Rutidosis leptorhynchoides* (3ECa): This species was once widespread in Victoria (Department of Conservation and Environment 1993a) and in the ACT–Queanbeyan region of NSW. Many populations, have recently been destroyed by urban expansion (Zich 1993b). Over 1000 plants are known from the two hectare Queanbeyan Nature Reserve but a larger population exists at site 336, in Community 1, at the north-western foot of Mount Jerrabomberra. This site is also threatened by urban development.
- *Dodonaea procumbens* (3V): This species was added to the national list due, in part, to the findings of this survey. It is distributed (West 1984) from the Lofty Ranges of South Australia, where small roadside populations remain, to the Penola and Grampians areas of Victoria where it is considered rare (J. Briggs pers. comm.) and to the Monaro in NSW where it has only been collected on the tilted shale bands running north from Bredbo. Here it grows in *Themeda australis–Poa sieberiana* grassland (Community 3a, Sites 355, 358).
- *Calotis glandulosa* (3VC-): The seven collections of this species in the NSW National Herbarium reveal that this species is mainly restricted to grasslands on the Monaro, with outlying collections at Oberon on the Central Tablelands and Mount Imlay on the South Coast. The accuracy of J.C. Boorman's 1916 record on Mount Imlay requires confirmation given that recent surveys have not located it in its vicinity (Keith and Sanders 1990). *Calotis glandulosa* was located once during this survey at site 356, Beloka Cemetery, in a *Themeda australis* dominated grassland protected from grazing (Community 3a). *Calotis glandulosa* has also been recently recorded from Bibbenluke Cemetery between Nimmitabel and Bombala (I. Lunt pers. comm.) and along the Dalgety–Jindabyne Road easement (G. Harden pers. comm.). These latest recordings suggest this species may be more common than previously thought, although it is notable that it tends to be restricted to areas where grazing is largely excluded. It therefore appears that grazing by stock may have led to a decline in abundance of *Calotis glandulosa* throughout its range.
- *Discaria pubescens* (3RCa): This species has a widespread distribution from Queensland to Victoria. It appears to decline with grazing pressure and seed-

> lings are rarely found (Department of Conservation and Natural Resources 1993b). It was recorded in two quadrats, 352 Adaminaby Hill (Figure 12) and 361 Round Plain Church. It is also known to occur in the TSRs at Adaminaby adjoining site 352. All sites where *Discaria pubescens* is recorded were fenced off from stock and are likely to have had a history of less intense or less frequent grazing. Herbarium records reveal this species is conserved in Kosciusko and Namadgi National Parks.

Wahlenbergia densifolia, previously listed as a rare species on the national list, was in five of the eight sites in Kosciusko National Park where it is under no threat and well conserved. It has therefore been removed from the ROTAP list (Briggs and Leigh in prep.).

Regionally rare species

Since the grassland ecosystems on the Monaro have been subject to major alteration since European settlement and little remains in good condition, it is logical that many grassland plant species would have declined in abundance during the same period. This particularly applies to inter-tussock, palatable forb species that have an upright habit (McIntyre 1993).

While 53 native species were recorded only once in the survey (Appendix 1) the vast majority of these are known to be common over their recorded range or common in other habitats. These include *Centrolepis strigosa, Podolepis hieracoides, Leptorhynchos elongatus, Swainsona behriana, Poa petrophila, Dichanthium sericeum, Dichelachne rara, Stipa blackii* and *Stipa densifolia.*

Species deemed to be regionally rare on the Tableland tract of the Monaro are *Diuris punctata, Swainsona monticola, Swainsona behriana, Stipa blackii, Senecio velleioides, Ranunculus sessiliflorus* var. *sessiliflorus, Podolepis hieracioides, Leptorhynchos elongatus* and *Solenogyne dominii*. Further surveys would refine this list.

This listing excludes species recorded in communities 6 and 7 that are located at higher elevations mainly in Kosciusko National Park. It is based on the frequency of each species recorded in this survey, herbarium records for the area and the author's knowledge of other habitats on the Southern Tablelands.

Discussion

The hypothesis of Cambage (1909) to explain the geographical distribution of natural grassland on the Monaro is largely supported by Ripley (1992) who states that grasslands throughout the world occur on a variety of substrates and landscapes but share the climatic characteristics of being subject to periodic drought and occurring in regions with a precipitation of between 350–800 mm. Titlyanova et al. (1990) add that the distribution of grassland is largely determined by the amount of available moisture in the soil. The lower altitude grasslands on the rainshadow-affected tableland tract of the Monaro fit with these findings.

The great prairie grasslands of North America and Russia grow on heavy chernozem soils, in low rainfall zones subject to drought (Moore 1964). Moisture availability in these heavy soils for the growth of trees is critical during dry times. Similar conditions prevail on the basalt plateau on the southern Monaro where *Poa sieberiana* is dominant (Community 4). A thick carbonate horizon is often present in these chernozem soils at less than 1 m depth (Costin 1954 and pers. comm.). This suggests that water does not percolate to a great depth. Given the low rainfall for this area, it is likely that the available moisture in the top layer of soil is exhausted by the dense herbaceous vegetation and tree seedlings may be outcompeted by a dense sward of grasses and forbs. When trees do grow they tend to occupy rocky ridges where ground vegetation is more sparse and where their roots can penetrate through cracks in rocks to the water table.

Some wetter parts of the Monaro grasslands may be subject to gradual recolonisation by shrub and tree species that survived the dry conditions of the last ice age in refuge areas, such as the coastal plain and escarpment (A. Costin pers. comm.). The montane and subalpine sod-tussock grasslands of Kosciusko National Park receive high precipitation and are less prone to drought. Tree growth is restricted in this area by frequent frosts and competition of tree seedlings with forbs and grasses (Harwood 1976).

Of the eight grassland groups described, communities 1, 2 and 3 (mostly occurring below 1000 m) appear to be most similar in species composition to the grasslands on the basaltic western plains of southern Victoria (based on comparisons in McDougall and Kirkpatrick 1993 and the discussion in Willis 1964).

The Monaro grasslands today

With the exception of the montane, sod-tussock grasslands (Communities 6 and 7) the grassland communities on the Monaro have been substantially modified since European settlement. Exotic species comprise over 35% of the flora in most places. It appears that many native plants have been eliminated or reduced in abundance through a history of intense grazing, competition with weeds and perhaps altered fire regimes. Although at most sites the bulk of the vegetation is composed of a small number of dominant native species, there is now an abundance of introduced annual species such as *Vulpia* occupying the inter-tussock space. Similar trends have been documented for other regions — Moore (1953) for inland NSW, and Barr and Cary (1992) for Victoria.

It is estimated that only a small fraction of the original extent of communities 1,2,3 and 5 remain in reasonable condition, that is, have a range of native species providing most of the biomass. The best remnants occur on roadsides, in church yards, cemeteries and in Travelling Stock Reserves. A shared feature of these places is that they have been fenced off from continual grazing and have not been subject to intensive pasture improvement or cropping. Similar findings have been documented for grasslands in Victoria (Stuwe 1986, McDougall et al. 1993).

Environmental determinants of communities

While altitude is the major determinant in the distribution of most species and the vegetation communities, the tall tussock *Poa labillardieri* grassland (Community 8) occurs at a range of altitudes and on a number of substrates. The main factor determining its distribution is landform position, since it is confined to drainage lines or river flats. These locations are moister than the surrounding slopes and probably act as nutrient drains and therefore provide a suitable habitat for many introduced plants which favour moist, higher nutrient sites (Doing 1972).

Most of the Monaro grasslands occur on heavy textured soils derived from fine grained sediments or volcanics, basalt or limestone. The sites grouped under Community 3 cover the greatest variation in substrate, soils and altitude. Their grouping is largely due to a shared dominance of *Themeda australis* and *Poa sieberiana*, and the common presence of other grass and forb species such as *Geranium solanderi* and

Stackhousia monogyna. The presence of a high diversity of inter-tussock forbs, many with an upright habit, may indicate a history of light (or at least intermittent) grazing at these sites. *Themeda australis* can quickly respond to summer rainfall and proliferates when grazing is excluded but does not withstand continued heavy grazing (Vickery 1961). Moore (1959) considers *Themeda australis* was dominant on much of the Tablelands in New South Wales, including the Monaro, prior to European settlement. It is also postulated to have been more widespread in the lowland grasslands of southern Victoria (McTaggart 1936, Barr & Cary 1992). During the initial stages of settlement on the Monaro, Lhotsky (1835) noted *Themeda* as abundant. It may have been a codominant with species of *Stipa* in Community 5 which is restricted to sandier soils derived from granite and sediments. This supposition is supported in Hancock (1972), quoting from the landholder Crisp, who refers to the changes in condition of grassland in the late 19th century at Jimenbuan, a settlement 25 km south of Dalgety situated on granite:

> *Free selection and the introduction of sheep put an end to extensive raising of cattle because of the loss of water in the main creek and because the best grasses for cattle disappeared and made way for a finer and, in my opinion, less nourishing grass. I have seen kangaroo grass, when in seed, like a field of wheat three feet high. This disappeared.*

The results of the extensive trials of the water requirements of agricultural plants undertaken by Shantz and Piemeisal (1927) showed that plants with the C3 photosynthetic system are better adapted in terms of water use efficiency, to cold temperatures and winter rainfall, while the malate-transporting C4 plants are more efficient with summer rainfall and warmer temperatures. *Themeda australis*, which is a C4 species, is probably not as well adapted photosynthetically to growing on the high basalt plateau south of Cooma (Community 4) as are the *Poa* species. *Themeda australis* does, however, exhibit a range of tolerances and other adaptations to the environment; indeed some ecotypes can grow in winter (Waterhouse 1993) and Groves (1975) found that separate populations contain varying flowering responses in relation to adaptions to different temperature regimes. *Themeda australis* may have existed in Community 4 as an inter-tussock subdominant before European settlement, if so it is now uncommon and must have been grazed out or outcompeted by *Poa* due to some unsubstantiated cause. *Poa sieberiana*, which is a C3 plant, is likely to have been a dominant in Community 4 at the time of European settlement as it is now. Conversely, *Themeda australis* may have adaptive advantages over *Poa sieberiana* at lower altitudes, such as in the vicinity of Dalgety or Bredbo, where the temperatures are warmer, soils are more permeable and drought more intense. *Themeda australis* may outcompete other species in these warmer climes in the absence of continuous grazing by its ability to respond quickly to summer rainstorms. The classification of Chan (1980) which lists eight grassland associations in the ACT would appear to fit as subdivisions under Community 1 (*Danthonia* dominated) and Community 2 (dominated by *Themeda australis* and *Bothriochloa macra*) derived in the present survey.

The results of the present survey suggest that the *Stipa scabra–Stipa bigeniculata* alliance mapped by Costin (1954) contains several distinct communities: Community 3, dominated by *Themeda australis* occurs mostly on sedimentary substrates in places such as Beloka, Bredbo and Adaminaby. Community 5, which is dominated by *Stipa scabra* subsp. *falcata* and *Stipa bigeniculata* occurs on sediments or granite near Cooma, Berridale and Dalgety, while the most distinctive and easily mappable unit, Community 4 (*Poa sieberiana*), covers the vast majority of the high basalt terrain. All of these communities contain *Stipa* species, which may explain their lumping by Costin (1954) at the alliance level. It may be better to redefine Costin's alliance as a *Poa sieberiana–Stipa scabra* subsp. *falcata–Stipa bigeniculata–Themeda australis* alliance.

Impact of grazing on plant communities

Differing grazing regimes may explain some of the differences between communities 3 and 5 on one hand, and communities 1 and 3 on the other. *Themeda australis* may have been largely eliminated from communities 1 and 5 leaving a dominance of hardier *Danthonia* and *Stipa* spp. respectively. It is possible, however, that *Danthonia* was always a major component of Community 1 (Edwards 1993). Therefore, it may be simplistic to describe the communities dominated by *Stipa* and *Danthonia* as 'disclimax' as suggested by Costin (1954), as these genera may have always have been abundant.

Because of the palatability of *Themeda australis*, sites where it is recorded as abundant are deemed to have a history of light grazing and therefore assessed as being in good condition. This includes most of the sites in Community 3 located in TSRs, railway easements, churchyards and cemeteries. Groves et al (1973) found that *Poa labillardieri* outcompeted *Themeda australis* in uptaking phosphorous and nitrogen when both species were grown together in pots. *Poa labillardieri* was found to contain more surface roots than *Themeda* which gave it an advantage in absorbing fertiliser nutrients from the topsoil. If it is assumed the same findings would apply to *Poa sieberiana*, then the widespread use of superphosphate on the Monaro may have advantaged *Poa sieberiana* over *Themeda australis* in communities 2–5. However, the previous discussion about the physiological advantage of the C3 *Poa* over the C4 *Themeda* under certain climatic regimes may provide a better explanation for the dominance of the former over the latter in Community 4, which occupies a region with low temperatures and naturally high nutrient soils. It is possible, however, that Community 3 represents something similar to the 'original' grassland of the lower altitudes in the study area. This is supported by its wide distribution on various substrates with the main common factor being that most sites have been protected from continuous heavy grazing. This may explain why communities 1,2,3 and 5 share many forb species but community 3 contains a greater proportion of upright forbs such as *Microseris lanceolata*, *Podolepis hieracioides* and *Bulbine bulbosa*.

The montane grasslands (communities 6 and 7) were grazed for over 100 years (Hancock 1972) (Snowy Plain is still grazed by sheep) but they have not been subject to pasture improvement or cultivation, although some areas may have been top-dressed with superphosphate. This would explain their relatively natural condition compared to the other grasslands in the study area.

Other types of grassland are present in the understorey of woodlands but these were not sampled in this survey. A distinctive example is the very tall, tussock grassland dominated by *Chionochloa pallida*. This was rarely observed and seemed to be restricted to poorer soils on quartz-rich ridges dominated by *Eucalyptus pauciflora* south of Cooma.

Rare grassland species

In a study of grassy vegetation on the Northern Tablelands of NSW McIntyre et al. (1993) suggest that inconspicuous, widespread, sparsely distributed species may have been overlooked in rare species listings. For many forbs in grassland, sparseness appears to be a common feature. This is supported by the floristic site data in Appendix 1 where a large proportion of grassland species was recorded in less than 5% of all quadrats. However, some of these species are common in adjoining woodlands and forests. The rarity of species recorded in this Monaro grasslands survey, as presented in the results section, was judged by a combination of measures including herbarium records, survey records and expert opinion. Herbaceous species of the

Monaro are not considered to be under-represented on the national rare plant list (Briggs and Leigh in prep.). Rather, the grassland ecosystems in the region are threatened and this has longer term implications for the continual survival of widespread herbaceous species in one region of south-eastern Australia.

Cover ratings and exotic species in classification

Many exotic species have been dispersed across the Monaro landscape through pasture-improvement programs (Wilson 1968, Douglas n.d.), and do not necessarily reflect complete naturalisation patterns. Therefore, it is not surprising that the UPGMA classification in which they were excluded was considered superior to those analyses that included them. It also appears that cover rating data gave a better result than using presence/absence data only. Others disagree (Kirkpatrick 1993 and pers. comm.) and consider that because the extent of cover of many grassland species varies considerably over time and with the seasons, presence/absence data is more meaningful. As far as the Monaro grasslands are concerned, most of the dominant native species are perennial, not annual or ephemeral. Cover ratings provide more information on this aspect of the floristics of the grasslands. This may explain why using cover ratings appeared to improve floristic classification. One danger of relying only on analyses using cover ratings may be that they overemphasise the importance of frequency variation in a few dominant species at the expense of less common species.

The UPGMA analysis may have been superior to the TWINSPAN analysis for the reasons outlined in Minchin (1987). Divisive classifications such as TWINSPAN classify deductively, and errors may accumulate as divisions are made in the sorting strategy. UPGMA makes no such assumptions, and calculates directly a hierarchical classification from the association measure matrix.

Management of remnants

Most research on native grasslands has concentrated on the use of native grasses as feed for stock (Roberts 1990, Munnich et al. 1991). Comparatively little is known about how to manage native grasslands for their intrinsic value, although there has been some research on the impact of mowing (Chan 1980) and fire (Lunt 1990). A review of lowland grassland management in Victoria is provided by Lunt (1991) and Kirkpatrick (1991) comments on managing Tasmanian natural grassland remnants.

Disturbance in grasslands would have occurred prior to European settlement through grazing and digging by native animals and by way of fire. Disturbance results in inter-tussock space which provides space for recruitment or resprouting of forbs. The survival of some forbs depends on light availability at ground level (Lunt 1993). Leaf arrangement (rosette versus erect) may explain differential survival rates of species grazed by stock (McIntyre 1993).

One of the main challenges to native grassland management is to understand how to impose disturbance that succeeds in stimulating seed germination (or resprouting) of native forbs in the inter-tussock gaps, without increasing invasion by weeds.

Fire

Given the early accounts of burning of the grassland vegetation on the Monaro by Aboriginal people (see Flood 1980, p. 285), grasslands are likely to have adapted to these fire regimes. These may have consisted of occasional patchy, low intensity fires, although it is presumed wildfires would have occasionally swept through landscape.

In 1824 the botanist Allan Cunningham observed Aborigines burning the 'Isabella' grassy plain in Autumn (Havard 1936), the present-day site of Tuggeronong, south of Canberra. Little is recorded about changes in frequency or intensity of fire after European settlement. A recent dendrochronological study of old *Callitris glaucophylla* trees in the nearby lower Snowy River valley (Pulsford 1991) has pointed to an increase in frequency and intensity of fires since then.

If burning regimes did change after Europeans arrived, there could have been detrimental impacts on some native plant species. However, data is lacking to even allow generalisations to be drawn about appropriate fire regimes in grasslands, although Lunt (1991) suggests *Themeda australis* grasslands should be burnt every five years. There is evidence, however, that different fire regimes may be required to maintain the native species diversity at different sites (Lunt 1993). Also, the benefits of fire to native plant diversity may be overwhelmed by post-fire weed invasion if a site has already been invaded by introduced species (Lunt 1990). Fire, however, appears to be necessary for the survival of *Swainsona recta* in the remnant grassland beside the Queanbeyan–Cooma railway easement (J. Briggs pers. comm.). As stated above, this species may require regular burning to keep competing grass species in check and stimulate seed germination or resprouting. The current lack of burning along the easement may be adversely affecting its population.

Site 361 Round Plain TSR has been burnt regularly by local landholders (B. Jardine pers. comm.) and it was recorded in this survey as being in good condition and worthy of nature reserve status.

Grazing

In 1862, one of the principal graziers in the Cooma district, James Litchfield, warned of the need for owners of large holdings to avoid overstocking and argued against tilling the soil in the region (Hancock 1972). This advice is just as relevant today.

Implementing appropriate grazing regimes is likely to be just as complicated as working out fire management. Only very general recommendations can be made. Some grazing may be beneficial for some sites, particularly if it is intermittent and carried out in autumn when most flowering and fruiting have finished. Year round, intense grazing (high stock numbers) is likely to eliminate some native species based on the findings that some species (including rare species) only survive in fenced off, non-grazed areas. At some sites the elimination of grazing altogether may, over time, lead to a simpler flora. Observations during a 1993 visit to site 364 (2CY Tower) in the ACT, two years after it was surveyed and two years after light grazing was removed, suggest that *Themeda* has increased its dominance and inter-tussock species have decreased in abundance.

The need to control the noxious weed *Hypericum perforatum* (St. Johns Wort) further complicates grazing management of grasslands. Currently, the Rural Lands Protection Board manages this weed on TSRs by spraying it with a herbicide or subjecting it to heavy grazing in spring before it can set seed (W. Phillips pers. comm.). This management, if carried out over important grassland sites, could conflict with protecting conservation values. It is therefore suggested that if *Hypericum perforatum* occurs in an important grassland site it should be treated by careful spraying or by a biological control agent (one demonstrated not to adversely affect native *Hypericum* species), but not by intensive spring grazing. Also, spelling an area from grazing for several years appears to reduce the population of this weed (R. Good pers. comm.).

Conservation

Concern for the loss of native pastures has long been expressed. Maiden (1898) was alarmed at the loss of native grasses and the increased dominance of introduced non-palatable weeds. He advised that efforts should be made to preserve native grasses as they are adapted to the conditions that prevail in the region.

Until recent times little attention has been paid to protecting and managing grasslands in reserves. They have not held the same appeal as forests or wetlands. This may be one reason why the grasslands of south-eastern Australia are poorly represented in reserves (McDougall and Kirkpatrick 1993).

No reserves have specifically been established to protect temperate grasslands on the tableland tract of the Southern Tablelands of NSW. Only one 150 ha nature reserve (Derrimut) has been permanently reserved for the protection of a lowland grassland ecosystem in Victoria, a State that has carried out extensive surveys of its grasslands, and this reserve is threatened by surrounding industrial development (Criagie 1993). Tunbridge Nature Reserve is the only place that samples natural grassland in the midlands of Tasmania.

The only grasslands protected on the Monaro are the montane, subalpine and alpine grasslands in Kosciusko and Namadgi National Parks. These are very different from the grasslands on the tableland tract (Figure 2).

More intensive surveys of grasslands in the ACT (Hogg 1990) have resulted in a large number of conservation proposals for that area. Also, research on the distribution of several rare fauna species (Edwards 1989, Osborne et al. 1991, S. Sharp pers. comm.) has resulted in conservation priorities that do not necessarily correspond to the priorities set by analysing floristics. For example, the Airport Beacon site (site 367) in the ACT contains three threatened species of animals (S. Sharp pers. comm.) but on the basis of its flora was not considered to be as important as other *Themeda*-dominated sites in the study area. Furthermore, Yen (1993) has shown, from work in Victoria, that the priorities for conserving grassland invertebrates do not necessarily match priorities set for protecting grasslands based on vascular plant data. More research is needed to examine the relationships between flora and fauna in grasslands to assist with grassland conservation.

Few options remain for the conservation of the tableland tract grasslands on the Monaro, but conservation efforts will be made easier because of the public ownership of most of the better remnants. A total of 23 sites of scientific significance have been identified (Table 3). This list includes 16 of the 17 sites documented in Benson and Wyse Jackson (1993). Given their scarcity, there is a valid argument that the remaining native grassland patches in good condition should be protected in reserves or by caveats attached to the title of the land (Table 3).

Public land, including travelling stock routes, containing native grassland should not be sold off to private landholders or leased for continual grazing. TSRs contain some of the best examples of native grassland and should be managed for conservation as well as catering for the needs of travelling stock. Some TSRs warrant stronger protection, either through dedication as nature reserves, or by way of management agreements drawn up under conservation agreements between the Rural Lands Protection Board and the NSW National Parks and Wildlife Service (Table 3). Maffra Lake TSR contains a stand of Community 4 grassland (not sampled in this survey) and contains one of the most important wetlands on the Monaro (Benson and Jacobs 1994). Reserving this TSR as a nature reserve would therefore result in achieving two nature conservation objectives.

Table 3. Grassland sites of the Monaro of scientific significance (excluding sites in Kosciusko National Park)

Site	Location	Community	Prot.	Justification	Management
336	Foot of Mt Jerrabomberra	1	NR	T1,C,D,R	LG,
348	Navy Navigational Centre ACT	1	NR	T2,M,R	LG,M,W
364	2CY Tower, ACT	2	NR	T2,C,M,R	LG,W
367	Airport Beacon, ACT	2	NR	T2,M	LG,W
363	Numeralla Cemetery	3a	CA	C,M,D	M,W
355	Haere Mai, Bredbo	3a	NR	T,C,M,D,R	LG,R
358	Nianna, Bredbo	3a	NR	T,C,M,D,R	LG,R
356	Beloka Cemetery	3a	CA	T,C,M	M,W,R
352	Adaminaby Hill*	3b	NR	T,C,M,D,R	LG,W,R
354	Yaouk	3b	CA	C,M,D,R	LG
357	Adaminaby Saleyards TSR	3b	CA	C,M	LG,W
361	Round Plain Uniting Church	3b	CA	T,C,M	M,W,R
353	Rail easement, Royalla	3b	NR	T,D	F,W,R
359	Round Plain TSR	3b	NR	C,M,R	F
420	Black Lake TSR	3b	NR	C,M,R	LG,W
339	Avon Lake TSR	4	CA	C,M,R	LG
340	Bondo TSR	4	CA	C,M,R	LG
342	North Brother TSR	4	CA	C,M,R	LG
343	Rock Flat TSR	4	CA	C,M,R	LG
341	Ravensworth TSR	4	CA	C,M,R	LG
377	Symonston	5	CA	R	LG
411	Snowy Plain	6	NP	C	LG
NA	Maffra Lake TSR**	4	NR	C,M	LG

Notes.

* Reservation of site 352 should be extended to include TSR No. 12. Alternatively, the private land portion of this area could be protected by a Conservation Agreement.

** Maffra Lake provides an opportunity to protect both a grassland and an important wetland in a reserve.

Prot. = Protection mechanism: NR = nature reserve, CA = conservation agreement

NP = add to existing national park

Justification: T1 = contains rare or threatened plant species

T2 = contains rare or threatened animal species

C = is in relatively good condition

M = is well fenced or easy to manage in other ways

D = contains a high diversity of native plant species

R = outstanding example of a plant community

Management: LG = light intermittent grazing based on past land use

M = irregular mowing of site

F = fire may be required based on past land use

W = weed control of major concern

R = monitoring and research of populations of rare species

The preparation of a conservation program for the native grassland remnants of the Monaro, similar to that produced for grassy vegetation in Victoria by the Victorian Department of Conservation and Environment (1993c), would be a worthy objective.

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Appendix 1. Frequency (%) of plant species recorded in native grassland communities and overall (* denotes introduced species;)

Species	Plant communities								Total
	1	2	3	4	5	6	7	8	
Acaena novae-zelandiae (Rosaceae)	–	–	–	–	–	–	–	33	3
Acaena ovina (Rosaceae)	40	17	88	87	10	86	–	–	52
*Acetosella vulgaris** (Polygonaceae)	–	50	47	–	50	57	67	33	39
Aciphylla simplicifolia (Apiaceae)	–	–	–	–	–	–	33	–	2
Acrotriche serrulata (Epacridaceae)	–	17	6	–	–	–	–	–	3
Agrostis aemula (Poaceae)	–	–	6	–	–	–	–	–	2
Agrostis avenacea var. *avenacea* (Poaceae)	–	–	–	–	–	–	–	17	2
Agrostis parviflora (Poaceae)	–	–	–	–	–	–	33	–	2
Agrostis venusta (Poaceae)	–	–	6	–	–	28	33	–	6
*Aira caryophyllea** (Poaceae)	–	–	41	12	30	14	33	17	23
*Aira elegantissima** (Poaceae)	80	83	41	12	10	–	–	–	29
*Arctotheca calendula** (Asteraceae)	20	–	–	–	–	–	–	–	2
*Arenaria serpyllifolia** (Caryophyllaceae)	–	–	–	12	–	–	–	–	2
Aristida ramosa var. *scaberula* (Poaceae)	40	–	6	–	–	–	–	–	5
Arthropodium milleflorum (Anthericaceae)	–	–	–	–	–	29	67	–	6
Asperula conferta (Rubiaceae)	60	50	35	87	20	43	–	–	39
Asperula gunnii (Rubiaceae)	–	–	–	–	–	14	100	–	6
Asperula scoparia (Rubiaceae)	–	–	–	–	–	29	–	17	5
*Avena barbata** (Poaceae)	–	33	12	–	–	–	–	–	6
Baeckea virgata (Myrtaceae)	–	17	–	–	–	–	–	–	2
Bothriochloa macra (Poaceae)	100	17	18	75	10	–	–	–	26
Brachycome aculeata (Asteraceae)	–	–	6	–	–	43	34	–	8
Brachycome heterodonta (Asteraceae)	–	–	12	–	10	–	–	–	5
Brachycome scapigera (Asteraceae)	–	–	–	–	–	43	100	–	10
Brachyloma daphnoides (Epacridaceae)	–	–	6	–	–	–	–	–	2
*Briza maxima** (Poaceae)	–	17	–	–	–	–	–	–	2
*Briza minor** (Poaceae)	40	50	12	–	–	–	–	–	11
*Bromus diandrus** (Poaceae)	–	17	–	–	10	–	–	–	3
*Bromus hordeaceus** (Poaceae)	80	100	23	37	60	–	–	50	42
*Bromus molliformis** (Poaceae)	–	–	–	25	–	–	–	–	3
Bulbine bulbosa (Asphodelaceae)	20	33	12	–	–	43	67	–	16
Calotis glandulosa (Asteraceae)	–	–	6	–	–	–	–	–	2
*Capsella bursa-pastoris** (Brassicaceae)	–	–	–	–	10	–	–	–	2
Cardamine paucijuga (Brassicaceae)	–	–	–	–	–	14	35	–	5
Carex appressa (Cyperaceae)	–	–	–	–	–	–	–	67	6

Appendix 1. (cont.)

Species	Plant communities								Total
	1	2	3	4	5	6	7	8	
Carex breviculmis (Cyperaceae)	–	–	–	–	–	14	–	–	2
Carex canescens (Cyperaceae)	–	–	–	–	–	14	–	–	2
Carex inversa (Cyperaceae)	20	67	47	37	40	–	–	50	37
Carex longebrachiata (Cyperaceae)	–	–	–	–	–	–	–	17	2
*Carthamus lanatus** (Asteraceae)	–	–	–	25	30	–	–	–	8
Celmisia asteliifolia (Asteraceae)	–	–	–	–	–	14	–		2
*Centaurium erythraea** (Gentianaceae)	–	50	35	–	–	–	–	–	14
Centrolepis strigosa (Centrolepidaceae) subsp. *strigosa**	–	17	–	–	–	–	–	–	2
Cerastium fontanum (Caryophyllaceae) subsp. *triviale**	–	–	6	–	–	14	67	17	8
*Cerastium glomeratum** (Caryophyllaceae)	–	33	17	12	–	–	–	17	11
Chamaesyce drummondii (Euphorbaceae)	20	17	6	–	40	–	–	–	8
Cheilanthes sieberi (Sinopteridaceae) subsp. *sieberi*	20	–	6	–	–	–	–	–	3
Chloris truncata (Poaceae)	–	–	–	–	10	–	–	–	2
Chrysocephalum apiculatum (Asteraceae)	80	33	82	75	30	–	–	–	47
Chrysocephalum semipapposum (Asteraceae)	20	–	12	–	–	–	–	–	5
*Cicendia quadrangularis** (Gentianaceae)	–	17	–	–	–	–	–	–	2
*Cirsium vulgare** (Asteraceae)	–	17	6	25	10	–	–	100	18
Convolvulus erubescens (Convolvulaceae)	60	17	47	75	40	–	–	–	35
Coprosma nivalis (Rubiaceae)	–	–	–	–	–	14	–	–	2
Craspedia coolaminica (Asteraceae)	–	–	–	–	–	86	–	–	10
Craspedia jamesii (Asteraceae)	–	–	–	–	–	–	67	–	4
Crassula sieberiana (Crassulaceae)	–	–	12	12	–	–	–	–	5
Cryptandra amara (Rhamnaceae)	–	–	6	–	–	–	–	–	2
Cymbonotus lawsonianus (Asteraceae)	40	17	12	–	10	–	–	–	10
Cymbonotus preissianus (Asteraceae)	–	–	–	–	–	14	67	–	5
Cynoglossum suaveolens (Boraginaceae)	20	17	6	–	–	–	–	–	5
*Dactylis glomerata** (Poaceae)	–	–	–	–	10	–	–	–	2
Danthonia auriculata (Poaceae)	40	–	–	–	–	–	–	–	3
Danthonia caespitosa (Poaceae)	–	17	35	75	70	–	–	–	32
Danthonia carphoides (Poaceae)	80	17	6	–	–	–	–	–	10
Danthonia laevis (Poaceae)	–	–	29	12	30	14	–	–	16
Danthonia linkii var. *linkii* (Poaceae)	–	–	6	–	30	–	–	–	6

Appendix 1. (cont.)

Species	Plant communities								Total
	1	2	3	4	5	6	7	8	
Danthonia monticola (Poaceae)	–	–	6	–	–	–	–	–	2
Danthonia nudiflora (Poaceae)	–	–	–	–	–	71	33	–	10
Danthonia pilosa var. *pilosa* (Poaceae)	–	–	6	–	–	–	–	–	2
Danthonia racemosa (Poaceae) var. *racemosa*	–	–	18	–	50	–	–	–	13
Daucus glochidiatus form F (Apiaceae)	–	–	–	12	–	–	–	–	2
Daviesia mimosoides (Fabaceae)	–	–	6	–	–	–	–	–	2
Daviesia ulicifolia (Fabaceae)	–	–	6	–	–	14	–	–	3
Desmodium varians (Fabaceae)	60	–	29	25	30	–	–	–	21
Dichanthium sericeum (Poaceae) subsp. *sericeum*	–	–	–	12	–	–	–	–	2
Dichelachne micrantha (Poaceae)	–	–	12	–	–	14	–	–	5
Dichelachne rara (Poaceae)	–	–	6	–	–	14	–	–	3
Dichondra sp. *A* (Convolvulaceae)	–	–	–	12	10	–	–	–	3
Dichondra repens (Convolvulaceae)	20	17	6	–	10	–	–	–	6
Dichopogon fimbriatus (Antheriaceae)	40	33	–	–	–	–	–	–	6
Discaria pubescens (Rhamnaceae)	–	–	12	–	–	–	–	–	3
Diuris punctata (Orchidaceae)	–	–	12	–	–	–	–	–	3
Dodonaea procumbens (Sapindaceae)	–	–	12	–	–	–	–	–	3
Drosera peltata (Droseraceae)	20	33	–	–	–	–	–	–	5
*Echium vulgare** (Boraginaceae)	–	–	–	12	–	–	–	–	2
Einadia nutans subsp. *nutans* (Chenopodiaceae)	–	–	–	–	10	–	–	–	2
Elymus scaber (Poaceae)	20	–	47	25	60	71	33	–	37
Enneapogon nigricans (Poaceae)	20	–	6	50	70	–	–	–	21
Epacris petrophila (Epacridaceae)	–	–	–	–	–	14	–	–	2
Epilobium billardierianum (Onagraceae) subsp. *cinereum*	–	–	41	25	–	57	100	33	29
Eragrostis brownii (Poaceae)	20	17	–	–	–	–	–	–	3
*Erodium cicutarium** (Geraniaceae)	–	–	–	–	10	–	–	–	2
*Erophila verna** (Brassicaceae)	–	–	6	50	10	–	–	–	10
Eryngium rostratum (Apiaceae)	40	50	–	12	10	–	–	–	11
Eucalyptus blakelyi (Myrtaceae)	–	–	6	–	–	–	–	–	2
Eucalyptus bridgesiana (Myrtaceae)	20	–	6	–	–	–	–	–	3
Eucalyptus melliodora (Myrtaceae)	–	–	12	–	–	–	–	–	3
Euphrasia collina (Scrophulariaceae) subsp. *paludosa*	–	–	–	–	–	14	–	–	2

Appendix 1. (cont.)

Species	Plant communities 1	2	3	4	5	6	7	8	Total
Festuca asperula (Poaceae)	–	–	6	–	–	29	67	–	8
*Galium divaricatum** (Rubiaceae)	20	–	6	–	–	–	–	–	3
Geranium antrorsum (Geraniaceae)	–	–	12	–	–	100	100	17	21
Geranium retrorsum (Geraniaceae)	–	–	29	–	–	–	–	33	11
Geranium solanderi (Geraniaceae)	–	–	35	12	–	–	–	–	11
Glyceria australis (Poaceae)	–	–	–	–	–	–	–	17	2
Glycine clandestina (Fabaceae)	–	–	23	–	–	–	–	–	6
Glycine tabacina (Fabaceae)	–	–	6	–	–	–	–	–	2
*Gnaphalium americanum** (Asteraceae)	–	–	6	–	–	–	–	–	2
Gnaphalium gymnocephalum (Asteraceae)	–	–	–	–	10	29	33	–	6
Gonocarpus tetragynus (Haloragaceae)	–	17	6	–	–	–	–	–	3
Goodenia pinnatifida (Goodeniaceae)	100	33	18	37	–	–	–	–	21
Hakea microcarpa (Proteaceae)	–	–	12	–	–	–	33	–	5
Haloragis heterophylla (Haloragaceae)	–	–	–	–	–	–	33	33	5
Hedypnois rhagadioloides (Asteraceae) subsp. *cretica**	20	–	–	–	–	–	–	–	2
Helichrysum scorpioides (Asteraceae)	–	–	6	–	–	–	33	–	3
Hemarthria uncinata (Poaceae) var. *uncinata*	–	–	–	–	–	–	–	17	2
*Hirschfeldia incana** (Brassicaceae)	–	–	–	–	10	–	–	–	2
*Holcus lanatus** (Poaceae)	–	17	–	–	–	–	–	50	6
*Hordeum leporinum** (Poaceae)	–	–	–	–	10	–	–	–	2
Hovea purpurea (Fabaceae)	–	–	–	–	–	14	–	–	2
Hydrocotyle laxiflora (Apiaceae)	20	–	6	–	–	–	–	–	3
Hydrocotyle peduncularis (Apiaceae)	–	–	–	–	–	–	33	33	5
Hydrocotyle gramineum (Clusiaceae)	20	33	23	12	–	–	–	–	13
Hydrocotyle japonicum (Clusiaceae)	–	–	–	–	–	–	33	–	2
*Hydrocotyle perforatum** (Clusiaceae)	–	17	–	–	–	–	–	–	2
*Hypochaeris glabra** (Asteraceae)	60	–	23	–	40	–	–	–	18
*Hypochaeris radicata** (Asteraceae)	60	100	82	50	60	71	67	50	69
Hypoxis hygrometrica (Hypoxidaceae) var. *hygrometrica*	–	–	–	–	–	–	33	–	2
Isolepis cernua (Cyperaceae)	–	–	–	–	–	–	–	17	2
Juncus australis (Juncaceae)	–	17	–	–	10	–	–	50	8
*Juncus bufonius** (Juncaceae)	20	33	–	–	–	–	–	17	6
*Juncus capitatus** (Juncaceae)	–	33	–	–	–	–	–	–	3

Appendix 1. (cont.)

Species	Plant communities 1	2	3	4	5	6	7	8	Total
Juncus filicaulis (Juncaceae)	–	83	–	12	–	–	33	50	16
*Lepidium africanum** (Brassicaceae)	–	–	6	–	10	–	–	–	3
Leptorhynchos elongatus (Asteraceae)	–	–	–	12	–	–	–	–	2
Leptorhynchos squamatus (Asteraceae)	40	33	71	12	–	100	67	–	42
Leptospermum lanigerum (Myrtaceae)	–	–	–	–	–	–	33	–	2
Leucopogon hookeri (Epacridaceae)	–	–	–	–	–	43	33	–	6
Limosella australis (Scrophulariaceae)	–	–	–	–	–	–	–	17	2
*Linaria arvensis** (Scrophulariaceae)	–	–	12	25	–	–	–	–	6
*Linaria pelisseriana** (Scrophulariaceae)	20	–	6	–	–	–	–	–	3
Linum marginale (Linaceae)	–	–	–	–	–	–	67	–	3
Lissanthe strigosa (Epacridaceae)	20	–	–	–	–	–	–	–	2
*Lolium perenne** (Poaceae)	20	–	–	–	10	–	–	17	5
Lomandra filiformis (Lomandraceae) subsp. *filiformis*	40	17	–	–	–	–	–	–	5
Lomandra multiflora (Lomandraceae)	20	33	18	–	–	–	–	–	10
Luzula densiflora (Juncaceae)	–	17	23	–	–	–	–	–	8
Luzula modesta (Juncaceae)	–	17	–	–	–	–	–	–	2
Luzula ovata (Juncaceae)	–	–	6	–	–	71	33	–	11
*Medicago lupulina** (Fabaceae)	–	–	6	25	–	–	–	–	5
*Medicago minima** (Fabaceae)	–	–	6	25	–	–	–	–	5
*Medicago sativa** (Fabaceae)	–	–	–	–	10	–	–	–	2
Melichrus urceolatus (Epacridaceae)	–	–	6	–	–	–	–	–	2
Microseris lanceolata (Asteraceae)	20	–	12	–	–	57	33	–	13
Microtis unifolia (Orchidaceae)	–	–	6	–	–	–	–	–	2
Mirbelia oxylobioides (Fabaceae)	–	–	12	–	–	–	–	–	3
*Moenchia erecta** (Caryophyllaceae)	80	17	12	–	20	–	–	–	14
Muehlenbeckia axillaris (Polygonaceae)	–	–	–	–	–	14	–	–	2
*Myosotis caespitosa** (Boraginaceae)	–	–	–	–	10	–	–	–	2
*Myosotis discolor** (Boraginaceae)	–	50	6	–	–	–	–	–	6
*Nassella trichotoma** (Poaceae)	20	17	–	–	–	–	–	17	5
Oenothera stricta (Onagraceae) subsp. *stricta**	–	–	6	–	–	–	–	–	2
Oreomyrrhis argentea (Apiaceae)	–	–	–	–	–	57	–	–	6
Oreomyrrhis eriopoda (Apiaceae)	–	–	18	12	20	29	33	–	14
Oxalis exilis (Oxalidaceae)	–	17	12	–	30	14	33	–	13
Oxalis perennans (Oxalidaceae)	20	17	18	12	20	14	33	–	16

Appendix 1. (cont.)

Species	Plant Communities								Total
	1	2	3	4	5	6	7	8	
*Parentucellia latifolia** (Scrophaceae)	80	–	–	–	–	–	–	–	6
*Paronychia brasiliana** (Caryophyllaceae)	–	–	–	–	40	–	–	–	6
Pentapogon quadrifidus (Poaceae)	–	–	–	–	–	29	33	–	5
Persoonia chamaepeuce (Proteaceae)	–	–	6	–	–	–	–	–	2
*Petrorhagia nanteuilii** (Caryophyllaceae)	–	–	59	75	30	–	–	–	31
Pimelea alpina (Thymelaeaceae)	–	–	–	–	–	27	–	–	3
Pimelea biflora (Thymelaeaceae)	–	–	–	–	–	14	–	–	2
Pimelea curviflora (Thymelaeaceae)	–	–	41	–	–	–	–	–	11
Pimelea glauca (Thymelaeaceae)	–	–	18	–	–	–	–	–	5
Plantago antarctica (Plantaginaceae)	–	–	–	–	–	86	–	–	10
*Plantago lanceolata** (Plantaginaceae)	60	50	23	37	10	–	–	17	24
Plantago varia (Plantaginaceae)	40	33	41	25	10	–	67	–	26
*Poa bulbosa** (Poaceae)	–	–	–	25	10	–	–	–	5
Poa costiniana (Poaceae)	–	–	–	–	–	29	100	–	8
Poa labillardieri (Poaceae)	20	33	–	–	–	14	–	100	16
Poa meionectes (Poaceae)	–	–	18	–	–	14	–	–	6
Poa petrophila (Poaceae)	–	–	6	–	–	14	–	–	3
Poa phillipsiana (Poaceae)	–	–	–	–	–	14	–	–	2
*Poa pratensis** (Poaceae)	–	17	6	25	–	–	–	83	14
Poa sieberiana (Poaceae)	20	33	88	100	40	85	–	–	58
Podolepis hieracioides (Asteraceae)	–	–	12	–	–	–	–	–	3
Podolepis robusta (Asteraceae)	–	–	–	–	–	71	–	–	8
Poranthera microphylla (Euphorbiaceae)	–	–	6	–	–	57	–	–	8
Prasophyllum alpinum (Orchidaceae)	–	–	–	–	–	14	67	–	5
Prasophyllum suttonii (Orchidaceae)	–	–	–	–	–	29	–	–	3
Pratia pedunculata (Lobeliaceae)	–	–	–	–	–	–	–	17	2
*Psilurus incurvus** (Poaceae)	20	–	–	–	–	–	–	–	2
Psoralea tenax (Fabaceae)	–	–	12	62	–	–	–	–	11
Pterostylis mutica (Orchidaceae)	60	–	–	–	–	–	–	–	5
Pultenaea fasciculata(Fabaceae)	–	–	6	–	–	29	–	–	5
Pultenaea polifolia (Fabaceae)	–	–	–	–	–	29	–	–	3
Ranunculus graniticola (Ranunculaceae)	–	–	–	–	–	85	67	–	13
Ranunculus lappaceus (Ranunculaceae)	–	–	23	–	–	–	–	–	6
Ranunculus pimpinellifolius (Ranuncaceae)	–	–	–	–	–	–	–	17	2

Appendix 1. (cont.)

Species	Plant Communities								Total
	1	2	3	4	5	6	7	8	
Ranunculus pumilio (Ranunculaceae) var. pumilio	–	–	–	–	–	–	–	17	2
Ranunculus sessiliflorus (Ranunculaceae) var. sessiliflorus	–	–	6	–	–	–	–	–	2
Restio australis (Restionaceae)	–	–	–	–	–	–	33	–	2
Rhodanthe anthemoides (Asteraceae)	–	–	–	–	–	29	–	–	3
Rhytidosporum alpinum (Pittosporaceae)	–	–	6	–	–	29	–	–	5
*Rosa rubiginosa** (Rosaceae)	–	17	18	12	–	–	–	17	10
Rumex brownii (Polygonaceae)	20	83	47	25	50	–	–	–	34
*Rumex crispus** (Polygonaceae)	–	–	–	–	–	–	–	33	3
Rutidosis leptorhynchoides (Asteraceae)	20	–	–	–	–	–	–	–	2
*Salvia verbenaca** (Lamiaceae)	–	–	18	62	40	–	–	–	19
Schoenusapogon (Cyperaceae)	20	50	23	–	–	–	33	–	14
Scleranthus biflorus (Caryophyllaceae)	–	–	18	–	10	100	67	–	21
Scleranthus diander (Caryophyllaceae)	–	–	18	62	20	–	–	–	16
Senecio lautus subsp. *alpinus* (Asteraceae)	–	–	–	–	–	57	–	–	6
Senecio quadridentatus (Asteraceae)	–	17	12	–	–	–	–	–	5
Senecio velleioides (Asteraceae)	–	–	–	–	–	19	–	–	2
Solenogyne dominii (Asteraceae)	–	–	–	–	30	–	–	–	5
Solenogyne gunnii (Asteraceae)	–	–	12	–	–	43	–	17	10
Sonchus asper (Asteraceae) subsp. *glaucescens**	–	–	6	–	–	–	–	–	2
*Spergularia rubra** (Caryophyllaceae)	–	–	–	–	10	–	–	–	2
Sphaerolobium vimineum (Fabaceae)	–	–	–	–	–	–	33	–	2
Stackhousia monogyna (Stackhousiaceae)	–	–	28	–	–	–	–	–	8
Stellaria angustifolia (Caryophyllaceae)	–	–	–	–	–	–	33	17	3
Stellaria multiflora (Caryophyllaceae)	–	–	–	–	–	–	33	–	2
Stipa bigeniculata (Poaceae)	60	17	18	62	90	–	–	–	34
Stipa blackii (Poaceae)	–	–	–	–	20	–	–	–	3
Stipa nodosa (Poaceae)	–	–	18	25	10	–	–	–	10
Stipa scabra subsp. *falcata* (Poaceae)	20	–	23	12	90	–	–	–	24
Stylidium graminifolium (Stylidiaceae)	–	–	12	–	–	14	100	–	35
Swainsona behriana (Fabaceae)	–	–	12	12	–	–	–	–	5
Swainsona monticola (Fabaceae)	–	–	6	12	–	29	–	–	6
Swainsona recta (Fabaceae)	–	–	12	–	–	–	–	–	3

Appendix 1. (cont.)

Species	Plant Communities								Total
	1	2	3	4	5	6	7		
Swainsona sericea (Fabaceae)	–	–	12	–	20	–	–	–	6
*Taraxacum officinale** (Asteraceae)	–	–	6	–	–	14	–	50	8
Themeda australis (Poaceae)	20	100	100	37	20	14	33	–	50
Trachymene humilis (Apiaceae) subsp. *humilis*	–	–	–	–	–	14	–	–	2
*Tragopogon dubius** (Asteraceae)	–	–	12	25	10	–	–	–	8
*Tragopogon porrifolius** (Asteraceae)	–	–	6	–	10	–	–	–	3
Tricoryne elatior (Anthericaceae)	20	–	–	–	–	–	–	–	2
*Trifolium angustifolium** (Fabaceae)	–	–	6	–	–	–	–	–	2
*Trifolium arvense** (Fabaceae)	40	–	76	62	57	–	–	–	44
*Trifolium campestre** (Fabaceae)	80	33	88	50	30	–	–	17	47
*Trifolium dubium** (Fabaceae)	80	67	12	–	20	–	33	67	27
*Trifolium glomeratum** (Fabaceae)	–	–	35	25	30	–	–	–	18
*Trifolium pratense** (Fabaceae)	–	–	6	–	–	–	–	–	2
*Trifolium repens** (Fabaceae)	–	–	23	12	–	29	67	33	18
*Trifolium striatum** (Fabaceae)	–	–	29	87	20	–	–	–	23
*Trifolium subterraneum** (Fabaceae)	80	50	12	–	40	–	–	17	23
Triptilodicus pygmaeus (Asteraceae)	60	33	18	–	10	–	–	–	14
Velleia paradoxa (Goodeniaceae)	–	–	–	–	–	29	–	–	3
Verbascum thapsus (Scrophulariaceae) subsp. *thapsus**	–	–	6	12	10	–	–	–	5
*Vaerbascum virgatum** (Scrophulariaceae)	–	17	18	–	–	–	–	–	6
*Veronica arvensis** (Scrophulariaceae)	–	–	6	–	–	–	–	17	3
Vaeronica calycina (Scrophulariaceae)	–	–	6	–	–	–	–	–	2
Viola betonicifolia (Violaceae)	–	–	6	–	–	29	33	–	6
Vittadinia cuneata (Asteraceae) var. *cuneata*	–	–	17	25	10	–	–	–	10
Vittadinia muelleri (Asteraceae)	80	17	23	12	50	–	–	–	24
*Vulpia bromoides** (Poaceae)	20	33	12	–	–	–	–	33	11
*Vulpia muralis** (Poaceae)	20	–	–	–	–	–	–	–	2
*Vulpia myuros** (Poaceae)	100	33	64	87	100	–	–	17	58
Wahlenbergia communis (Campanulaceae)	60	–	41	62	60	–	–	–	34
Wahlenbergia densifolia (Campanulaceae)	–	–	–	–	–	71	–	–	8
Wahlenbergia gracilis (Campanulaceae)	–	–	–	–	20	–	–	–	3
Wahlenbergia multicaulis (Campanulaceae)	20	–	23	–	–	–	100	–	13
Wurmbea dioica (Colchicaceae)	20	16	6	–	–	–	–	–	5

Plant communities of the Monaro lakes

J.S. Benson and S.W.L. Jacobs

Benson, J.S. & Jacobs, S.W.L., (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, NSW, Australia 2000) 1994. Plant communities of the Monaro lakes. Cunninghamia *3(3): 651–676.* Four wetland plant communities were defined from a cluster analysis of plant species recorded from 65 lakes in the southern Monaro region, Southern Tablelands of New South Wales (c. Lat. 36° 00'–37° 00' S Long. 148° 30'–149° 20' E). 110 plant species (including 19% exotic) were recorded from the lakes and their strandlines. Several species were collected for the first time on the Southern Tablelands. Altitude, size of lakes and permanence of water appear to be the main factors directly or indirectly determining floristic variation between the lakes, whereas substrate appears not to be important in this regard. We postulate that wave action on large lakes may limit the survival of floating-attached waterplants. Further study is required to establish the importance of lake size and shape, and salinity on species distribution. A number of lakes judged to be in sound condition or containing significant species are proposed for conservation.

Introduction

Over the last 25 years there have been a number of botanical, limnological and waterfowl surveys of wetlands in south-eastern Australia. Jacobs and Brock (1993) review the literature on wetland studies in southern (temperate) Australia and provide an assessment of the classification systems used. Other major contributions include a survey of the coastal saltmarsh plant communities in New South Wales by Adam et al. (1988), the review of wetlands in Victoria by Norman and Corrick (1988), the review of Tasmanian wetlands by Kirkpatrick and Tyler (1988), and the description of Tasmanian wetland plant communities by Kirkpatrick and Harwood (1983).

There is limited documentation of the waterplants growing on the Tablelands compared to the coastal wetlands in New South Wales. Exceptions include the peat swamps on the Southern Tablelands (Hope & Southern 1980), and a number of Northern Tablelands wetlands (Briggs 1976, Bell 1992) which are also subject to current research on the seedbank dynamics of wetland communities (Brock & Britton in press, M. Brock pers. comm.). The vegetation of the alpine and subalpine swamps in Kosciusko National Park were documented in Wimbush and Costin (1979a & b).

The aim of our survey was to record the waterplants growing in the lakes on the tableland tract of the southern Monaro region (Costin 1954), to classify the wetland plant communities, suggest possible explanations for the distribution of those plant communities and their constituent species, comment on the conservation status of the wetland communities, and make suggestions on how to improve conservation.

The study area

The survey concentrated on the near-permanent (rarely dry), intermittent (often seasonally dry) and ephemeral (occasionally full) lakes on the tableland tract of the southern Monaro from Bullanamung Lake (Lat. 36° 00' 15"), 28 km north of Cooma, to Green Lake (Lat. 37° 01' 35"), 15 km south of Bombala. These lakes would be classified as Mountain Lakes and Swamps, (a) perennial lakes and (c) ephemeral

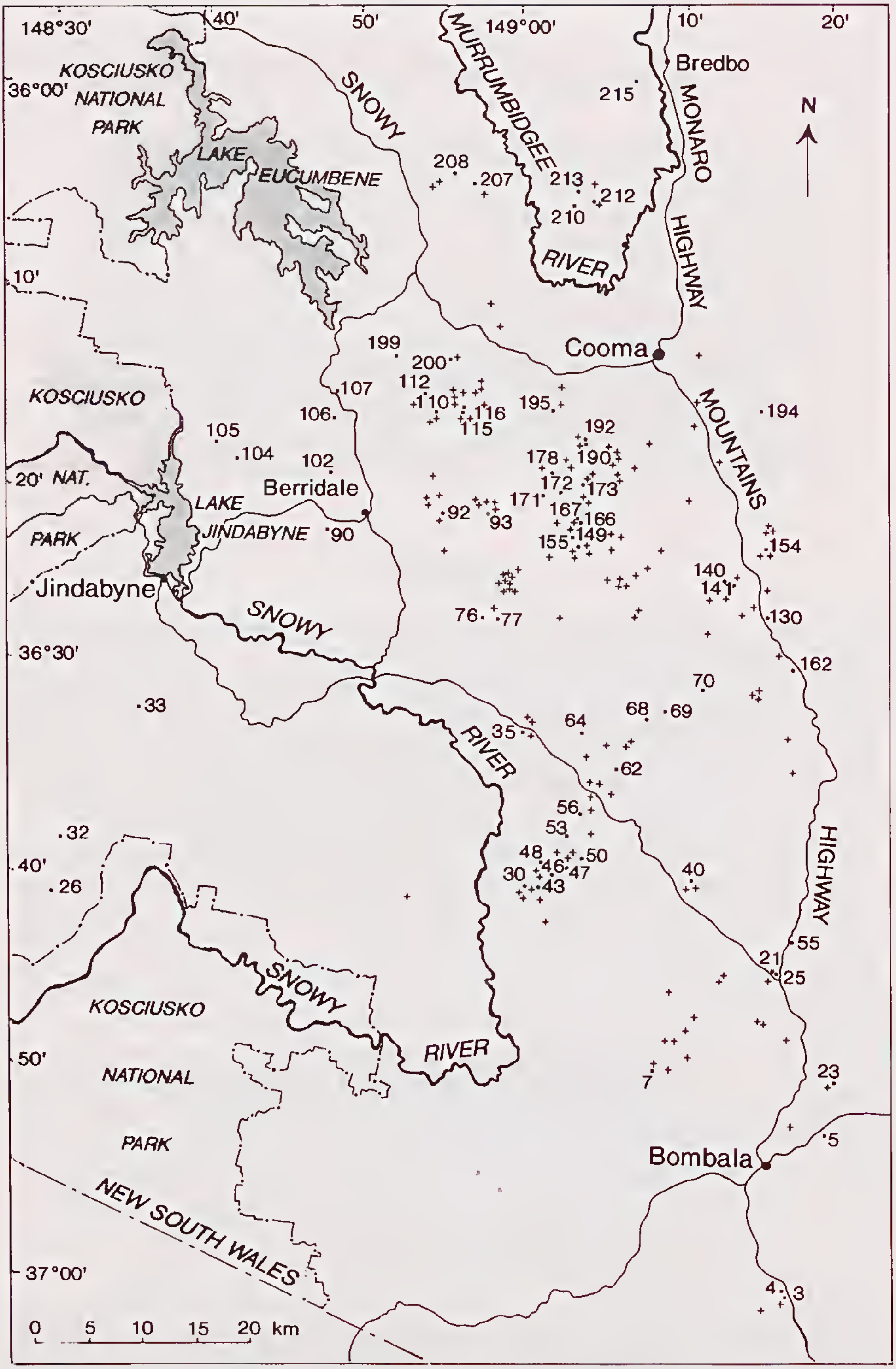


Figure 1. Distribution of the 215 lakes on the southern Monaro; the 65 lakes sampled during this survey are numbered (see also Appendix 1).

lakes/swamps, in the classification suggested by Jacobs and Brock (1993). The region is bounded in the east by the South Coast and Kybean Ranges and in the west by the steep eastern escarpment of Kosciusko National Park (Figure 1). Glacial lakes and swamps in the alpine tract of the Monaro (Kosciusko National Park), or wetlands formed by depositional processes such as backswamps, were not included in the survey.

Most of the lakes are between 800 and 1100 m altitude. The lowest elevation of 760 m (lakes 1–3 Figure 1, including Green Lake) was recorded south of Bombala and the highest elevation of 1220 m on the Monaro Range near Middlingbank north of Berridale (lake 199, Figure 1). Rainfall ranges from 450 to 700 mm per annum with falls mainly in the winter (Costin 1954). Temperatures are cold in winter and mild in summer.

The land-use history of the region is summarised in Benson (1994). Most lakes are on private land that has been grazed by sheep and/or cattle for over 100 years. The intensity of grazing has probably varied from property to property. Little is documented about the extent of lake bed cropping in the region, but discussions with landholders indicate that it has been limited compared to the level of cropping on the lake beds of inland New South Wales.

Geomorphology

The Monaro lakes fall within the 'lentic tablelands' wetland geomorphological definition of Pressey and Harris (1988). Of the 215 lakes on the Monaro, the majority (185, or 86%) are on Eocene basalt; 17 (8%) are on granitic rock types; 4 (2%) are on sedimentary or metamorphic rocks; and 9 (4%) are at the junction of basalt and granitic rocks (Appendix 1). The lake beds are composed of varying depths of dark-grey cracking clays often incorporating carbonate nodules (Pillans 1987).

The most likely explanation for the formation of the Monaro lakes is the process of deflation during the last ice age (Pillans 1987). Lakes on basalt terrain in the midlands of Tasmania are also considered to have formed by deflation (Kirkpatrick & Tyler 1988). Similarly formed lakes are those on the undulating pampa in Argentina and Uruguay in South America (Soriana 1992). Since deflation lakes tend to occur in landscapes dominated by grassland vegetation; the climatic and soil property requirements for the maintenance of grassland — low precipitation, periodic droughts and heavy textured soils (Benson 1994) — are also important for maintenance of the lakes. Such a climate leads to frequent drying out of the lakes, and accumulated sediments on the lake beds are blown away in dry times. Most of the Monaro lakes have aeolian sediment 'shadows' spreading from their eastern shores. These are composed of clay pellets formed during lake-bed surface drying (Pillans 1987). Lake lunettes are rare.

The largest and deepest lakes in the study area dry out only during prolonged drought. Some of these are situated at the junction of basalt flows and granite (examples include Maffra, Boundary, Buckleys and Cootralantra Lakes). Their origin may not be solely due to deflation. During volcanic activity in the Eocene, basalt flows may have dammed valleys and formed depressions in the landscape. These could subsequently have developed into lakes (G. Taylor pers. comm.).

Methods

Data collection

Lakes and wetland depressions greater than one hectare are shown on the 1:25 000 scale topographic maps covering the region (Land Information Centre, Department of Conservation and Land Management 1971–1988). We numbered the lakes from south to north (Figure 1), and their size, altitude and substrate (Australian Geological Survey 1964) were documented (Appendix 1). Artificial dams or impounded lakes were excluded from the survey.

Major environmental variables likely to influence the floristic composition of the lakes included size of lake, degree of permanence, altitude, geography and substrate. Approximately 70% of the large lakes (> 10 ha) and 16% of the more numerous small lakes (< 3 ha) were surveyed (Figure 2).

Sampling took place in February 1993 after a wetter than normal spring and summer (Bob Wilkinson pers. comm.) when the lakes were near-full. Some ephemeral lakes had already dried. This timing ensured that most aquatic species were flowering or fruiting.

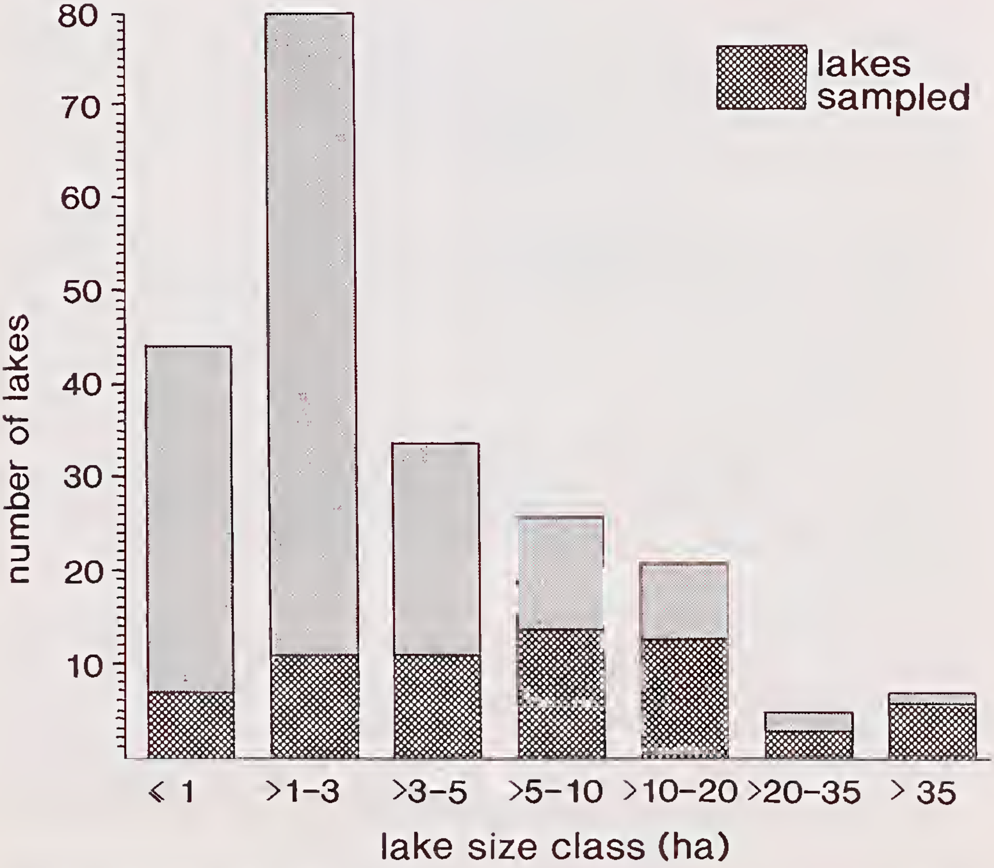


Figure 2. Numbers of lakes in size classes showing the proportion of each class sampled.

At each lake all species were recorded and assigned a cover rating on a six-point scale; 0–1, 2–5, 6–25, 26–50, 50–75, 76–100%. Species were recorded from both the water and the adjoining strandline, which varies in position and width as water levels rise and fall. Each wetland was treated as a single site — all plants on the strandline (regularly inundated section of the shoreline) and growing in the water were combined and treated together. Lakes were circumnavigated or traversed by foot. In deeper lakes several sorties were made from the shore and, in the largest, a small boat was used. Any sign or suggestion of vegetation in water was checked and identified. Standard-sized quadrats were not used and, sample size varied substantially, but this was not seen as a confounding factor because of the ease of dispersal of waterplants within water bodies. The lakes were sampled only once. Given the ephemeral nature of some of these lakes and the life cycle of many waterplants, the abundance and presence of some species would vary over time. We are confident, however, that most waterplant species from the lakes would persist and be recorded in future surveys.

Data analysis

The sample sites and species were classified into floristic groups using an agglomerative hierarchical classification with the Kulcynski coefficient dissimilarity measure, and applying the flexible unweighted paired group arithmetic averaging (UPGMA) sorting strategy of PATN (Belbin 1993). The benefits of using the Kulczynski coefficient compared to other measures are discussed in Faith, Minchin and Belbin (1987). They found it was most robust to variations in assumed models of species response. The analysis incorporated the species cover rating data in a matrix of 65 sites by 110 species. Exotic species were included.

Selection of three floristic groups (Communities 2, 3 and 4) was made at the 0.85 dissimilarity measure. One group (Community 1) was selected at the 0.78 measure.

A two-way table was generated using the 2-step association measure on species and Kulczyski coefficient on sites (Belbin 1993). This aided in identifying common and indicator plant species in each UPGMA-selected floristic group. The mean plant species richness for the lakes selected into each floristic group (plant community) was calculated. The mean size of the lakes classified into the floristic groups was also calculated.

Hybrid non-metric multidimensional scaling (NMDS) using PATN (Belbin 1993) was used to ordinate the lake floristic data along three vectors. To test the nature of the environmental space being described by these vectors, simple relationships of the selected floristic groups (1-4) with the environmental attributes substrate, altitude and size of lake were investigated. Means and medians of altitude, lake size and geology were derived using the GSTA (group statistics) module of PATN.

Results

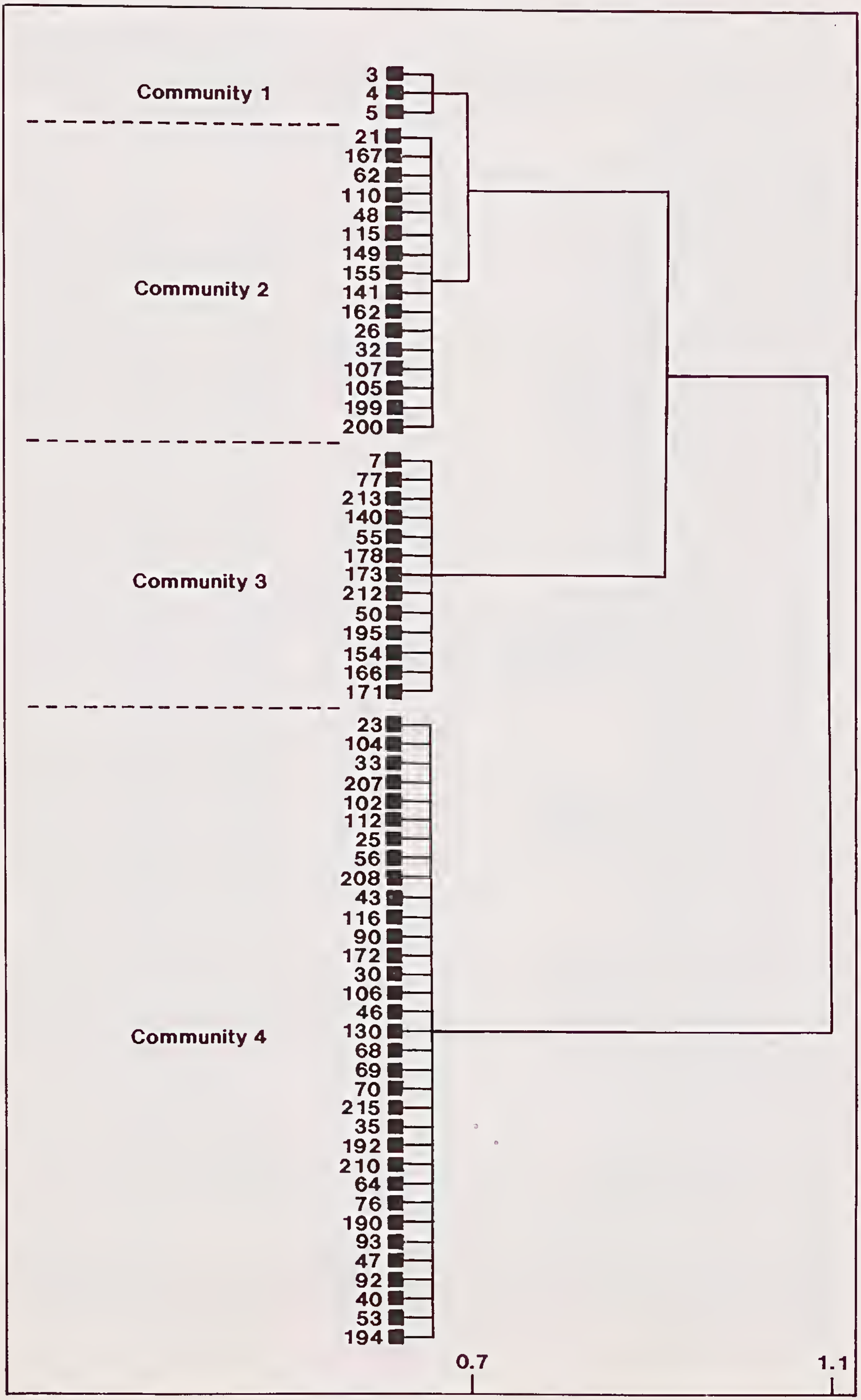
The numbered lakes shown on Figure 1 are those sampled in this survey. Figure 2 summarises the number of lakes in several size classes and the proportion of each class sampled. The classification of the sampled lakes into floristic communities is presented in Figure 3. Community classification is based on Kirkpatrick and Tyler (1988).

Table 1. Percentage frequency of plant species recorded in each wetland plant community and for all sites

Community 1 = shallow freshwater herb-sedge marsh, low elevations
Community 2 = shallow freshwater herb-herb marsh, high elevations
Community 3 = shallow ephemeral freshwater herb-grass marsh
Community 4 = deep freshwater sedge-herb marsh
* = exotic species

Species	**Community (%)**				
	1	**2**	**3**	**4**	**All**
Agrostis avenacea var. *avenacea* (Poaceae)	100	87	100	91	92
Alisma plantago-aquatica (Alismataceae)	0	6	0	0	1
Amphibromus nervosus (Poaceae)	67	100	39	12	42
Asperula conferta (Rubiaceae)	0	6	0	0	1
Australopyrum retrofractum (Poaceae)	0	6	0	0	1
Azolla filiculoides var. *rubra* (Azollaceae)	0	12	0	3	5
**Batrachium trichophyllum* (Ranunculaceae)	33	0	0	3	3
Bolboschoenus caldwellii (Cyperaceae)	0	0	0	9	5
Brachycome radicans (Asteraceae)	33	25	8	3	11
**Callitriche stagnalis* (Callitrichaceae)	0	0	0	3	1
Cardamine tenuifolia (Brassicaceae)	0	0	8	3	3
Carex bichenoviana (Cyperaceae)	0	19	15	79	48
Carex gaudichaudiana (Cyperaceae)	0	12	0	0	3
Carex inversa (Cyperaceae)	0	0	0	6	3
Carex tereticaulis (Cyperaceae)	33	25	8	33	26
**Centaurium erythraea* (Gentianaceae)	0	0	0	6	3
Centipeda cunninghamii (Asteraceae)	66	44	69	15	35
Chenopodium glaucum (Chenopodiaceae)	0	0	8	30	17
Chenopodium pumilio (Chenopodiaceae)	0	6	8	0	3
**Cirsium vulgare* (Asteraceae)	0	0	15	6	6
Crassula helmsii (Crassulaceae)	66	44	23	85	62
Cyperus lhotskyanus (Cyperaceae)	0	6	0	6	5
Deyeuxia quadriseta (Poaceae)	0	12	0	0	3
Dichondra repens (Convolvulaceae)	0	0	0	3	1
Elatine gratioloides (Elatinaceae)	33	6	15	0	6
Eleocharis acuta (Cyperaceae)	100	100	69	73	78
Eleocharis atricha (Cyperaceae)	0	0	0	9	5
Eleocharis gracilis (Cyperaceae)	0	0	0	6	3
Eleocharis pusilla (Cyperaceae)	33	62	31	39	43
Eleocharis sphacelata (Cyperaceae)	100	0	0	0	5
Epilobium billardierianum subsp. *cinereum* (Onagraceae)	33	0	0	3	3
**Festuca elatior* (Poaceae)	0	0	0	3	1
Glossostigma elatinoides (Scrophulariaceae)	66	87	30	21	41
Glyceria australis (Poaceae)	33	0	0	0	1
Gnaphalium sphaericum (Asteraceae)	100	31	0	21	23
Helichrysum scorpioides (Asteraceae)	33	0	0	0	1
Hemarthria uncinata var. *uncinata* (Poaceae)	33	19	0	9	11
**Holcus lanatus* (Poaceae)	33	0	8	12	9
**Hordeum marinum* (Poaceae)	0	12	8	52	31
Hydrocotyle algida (Apiaceae)	0	0	0	3	1
Hydrocotyle peduncularis (Apiaceae)	100	88	8	30	43
Hypericum gramineum (Clusiaceae)	33	0	0	0	1
**Hypochaeris radicata* (Asteraceae)	0	0	8	3	3
Blue green algae	0	0	8	0	1
Chara sp.	66	37	15	67	49
Green algae	0	6	8	39	23
Isolepis fluitans (Cyperaceae)	66	0	8	0	5
Isolepis platycarpa (Cyperaceae)	33	31	69	27	37
Isolepis subtilissima (Cyperaceae)	33	0	0	0	1
Juncus articulatus (Juncaceae)	100	56	8	42	42

Juncus australis (Juncaceae)	66	50	0	30	31
**Juncus bufonius* (Juncaceae)	0	12	15	24	18
Juncus holoschoenus (Juncaceae)	33	19	0	0	6
Juncus sp. (Juncaceae)	66	37	0	12	18
Juncus subsecundus (Juncaceae)	66	12	15	18	18
Juncus usitatus (Juncaceae)	33	19	0	0	6
Juncus vaginatus (Juncaceae)	33	25	0	36	26
Lemna disperma (Lemnaceae)	33	6	0	9	8
Lepilaena bilocularis (Zannichelliaceae)	0	0	0	64	32
Lilaeopsis polyantha (Apiaceae)	66	12	0	6	9
Limosella australis (Schrophulariaceae)	33	37	62	88	68
Lythrum hyssopifolia (Lythraceae)	33	0	0	0	1
Marsilea angustifolia (Marsileaceae)	0	50	38	3	22
Marsilea drummondii (Marsileaceae)	33	12	15	6	11
Mentha diemenica (Lamiaceae)	0	12	0	3	5
Myriophyllum caput-medusae (Haloragaceae)	0	37	0	6	12
Myriophyllum simulans (Haloragaceae)	100	100	8	3	32
Myriophyllum verrucosum (Haloragaceae)	0	6	8	30	18
Neopaxia australasica (Portulaceae)	0	31	0	0	8
Nymphoides montana (Menyanthaceae)	66	0	0	0	3
Ottelia ovalifolia (Hydrocharitaceae)	0	19	0	0	5
Paspalum distichum (Poaceae)	0	0	8	3	3
Persicaria decipiens (Polygonaceae)	0	0	0	3	1
Persicaria maculosa (Polygonaceae)	0	19	31	6	14
Persicaria prostrata (Polygonaceae)	33	44	54	36	42
**Phalaris aquatica* (Poaceae)	0	6	0	0	1
**Polypogon monspeliensis* (Poaceae)	0	0	0	18	9
Potamogeton crispus (Potamogetonaceae)	33	19	8	6	11
Potamogeton ochreatus (Potamogetonaceae)	66	37	31	36	37
Potamogeton tricarinatus (Potamogetonaceae)	100	100	46	15	46
**Potentilla anserina* subsp. *anserina* (Rosaceae)	0	6	0	9	6
Pratia surrepens (Lobeliaceae)	100	25	0	0	11
Psoralea tenax (Fabaceae)	0	0	0	6	3
Puccinellia stricta (Poaceae)	0	0	31	30	22
Ranunculus inundatus (Ranunculaceae)	100	94	15	3	32
Ranunculus sceleratus (Ranunculaceae)	0	6	0	9	6
Ranunculus diminutus (Ranunculaceae)	0	37	15	97	62
Rorippa palustris (Brassicaceae)	0	0	8	3	3
Rumex brownii (Polygonaceae)	0	12	0	6	6
**Rumex crispus* (Polygonaceae)	33	37	23	52	42
Rumex tenax (Polygonaceae)	33	6	0	0	3
Ruppia megacarpa (Potamogetonaceae)	0	0	0	3	1
Ruppia polycarpa (Potamogetonaceae)	0	0	0	3	1
**Salix alba* (Salicaceae)	33	0	0	3	3
Schoenoplectus pungens (Cyperaceae)	0	0	0	24	12
Schoenus apogon (Cyperaceae)	33	6	0	12	9
Schoenus nitens (Cyperaceae)	0	0	0	3	1
Stellaria angustifolia (Caryophyllaceae)	0	31	8	6	12
**Trifolium campestre* (Fabaceae)	0	6	0	0	1
**Trifolium dubium* (Fabaceae)	0	0	15	15	11
**Trifolium fragiferum* (Fabaceae)	0	0	0	3	1
**Trifolium glomeratum* (Fabaceae)	0	0	15	3	5
**Trifolium repens* (Fabaceae)	0	19	23	18	19
Utricularia monanthos (Lentibulariaceae)	33	0	0	0	1
Vallisneria gigantea (Hydrocharitaceae)	66	0	0	0	3
**Veronica anagallis-aquatica* (Scrophulariaceae)	0	25	8	21	18
Villarsia exaltata (Menyanthaceae)	33	0	0	0	1
Viola hederacea (Violaceae)	0	0	8	0	1
**Vulpia myuros* (Poaceae)	0	0	0	3	1
Wolffia australiana (Lemnaceae)	33	6	0	3	5


Community 1
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Community 3
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Community 4
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Floristics

A total of 110 species was recorded during the survey, of which 21 (19%) species were exotic (Table 1). Nomenclature follows Harden (1990–93).

The most commonly recorded native species were *Agrostis avenacea* (in 92% of sites), *Eleocharis acuta* (78%), *Limosella australis* (68%), *Crassula helmsii* (62%), *Ranunculus diminutus* (62%), *Carex bichenoviana* (48%), *Potamogeton tricarinatus* (46%), *Amphibromus nervosus* (42%), *Juncus articulatus* (42%) and *Hydrocotyle peduncularis* (43%).

The most common exotic species were *Rumex crispus* (42%), *Hordeum marinum* (31%), *Trifolium repens* (18%) and *Veronica anagallis-aquatica* (18%).

Native species recorded only once during the survey include *Ruppia megacarpa*, *R. polycarpa*, *Villarsia exaltata*, *Lythrum hyssopifolia*, *Isolepis subtilissima*, *Alisma plantago-aquatica* and *Australopyrum retrofractum*.

Cardamine tenuifolia was recorded for the first time in New South Wales and other native species including *Ruppia polycarpa*, *Myriophyllum simulans*, *Marsilea angustifolia* and an undescribed form of *Marsilea drummondii* were recorded for the first time on the Southern Tablelands. The exotic forb *Potentilla anserina* subsp. *anserina* was also recorded for the first time on the Southern Tablelands.

The submerged aquatic *Lepilaena bilocularis* and strandline sedge *Carex bichenoviana*, were found to be more common in the region than previously indicated from herbarium records.

Wetland plant communities

The structure and species composition of the four wetland communities are described below. Dominant species are commonly recorded species with high cover ratings that may be found in more than one community. Indicator species are plants that are largely confined to one type of community.

Community 1. Shallow freshwater herb-sedge marsh: *Myriophyllum simulans–Eleocharis sphacelata–Nymphoides montana–Pratia surrepens*

Structure: Tall emergent sedge layer over part of the lake. A large proportion of the surface of the lake is covered with floating-attached or emergent waterplants and there is usually a dense mat of forbs covering the strandline. (Figure 4.)

No. samples: 3

Mean lake size: 5 ± 1.5 ha.

Mean no. native sp.: 28 ± 4

Mean no. exotic sp.: 2 ± 1

Dominant species: *Myriophyllum simulans*, *Potamogeton tricarinatus*, *Eleocharis sphacelata*, *Nymphoides montana*, *Pratia surrepens*, *Hydrocotyle peduncularis*, *Eleocharis acuta*, *Agrostis avenacea*.

Indicator species: *Eleocharis sphacelata*, *Nymphoides montana*, *Pratia surrepens*, *Hydrocotyle peduncularis*, *Isolepis fluitans*, *Glyceria australis*, *Vallisneria gigantea* and *Utricularia monanthos*.

Substrate and distribution: Found in lakes on granitic and basalt substrates at lower altitudes (760–830 m) in the Bombala district. This area receives a higher rainfall than the rest of the study area.

Figure 3 (left). Agglomerative classification of lakes (see Appendix 1 for lake numbers) by their similarity of plant composition selected at the 0.78 disassociation value. This analysis is based on cover ratings for both native and exotic species.

Comment: Community 1 is restricted to small lakes (< 5 ha) in the far south-eastern section of the study area at relatively lower altitudes (a median at 760 m). It contains a high number of native species. Many of the species in Community 1 are also found in Community 2, but, within the study area, several species, such as the floating-attached *Nymphoides montana*, are confined to it.

Community 2. Shallow freshwater sedge-herb marsh: *Myriophyllum simulans–Potamogeton tricarinatus–Eleocharis acuta–Glossostigma elatinoides–Amphibromus nervosus*

Structure: Short sedge layer over-topping a dense forb ground cover on strandline. Extensive emergent and floating-attached waterplants present on the surface of the lakes. (Figure 5.)

No. samples: 16

Mean lake size: 3 ± 2 ha.

Mean no. native sp.: 20 ± 5

Mean no. exotic sp.: 1 ± 0.9

Dominant species: *Myriophyllum simulans, Potamogeton tricarinatus, Eleocharis acuta, Glossostigma elatinoides, Amphibromus nervosus, Agrostis avenacea, Eleocharis pusilla.*

Indicator species: *Myriophyllum caput-medusae, Stellaria angustifolia, Neopaxia australasica, Ottelia ovalifolia, Carex gaudichaudiana.*

Substrate and distribution: Found in deflation lakes on basalt south of Cooma with a sub-group (lakes 26, 32, 107, 105, 199, and 200) in deflation lakes on granite near Berridale and Jindabyne. This community occurs at higher altitudes than the others in the study area, ranging from 880 m to 1220 m.

Comment: Community 2 is mainly recorded from small to medium, intermittent lakes (median 2 ha) at high altitudes (median 1030 m). These lakes contain a high native species richness with an abundance of the floating-attached waterplant *Potamogeton tricarinatus* and the submerged or emergent *Myriophyllum simulans*. Few exotic species were recorded from this community.

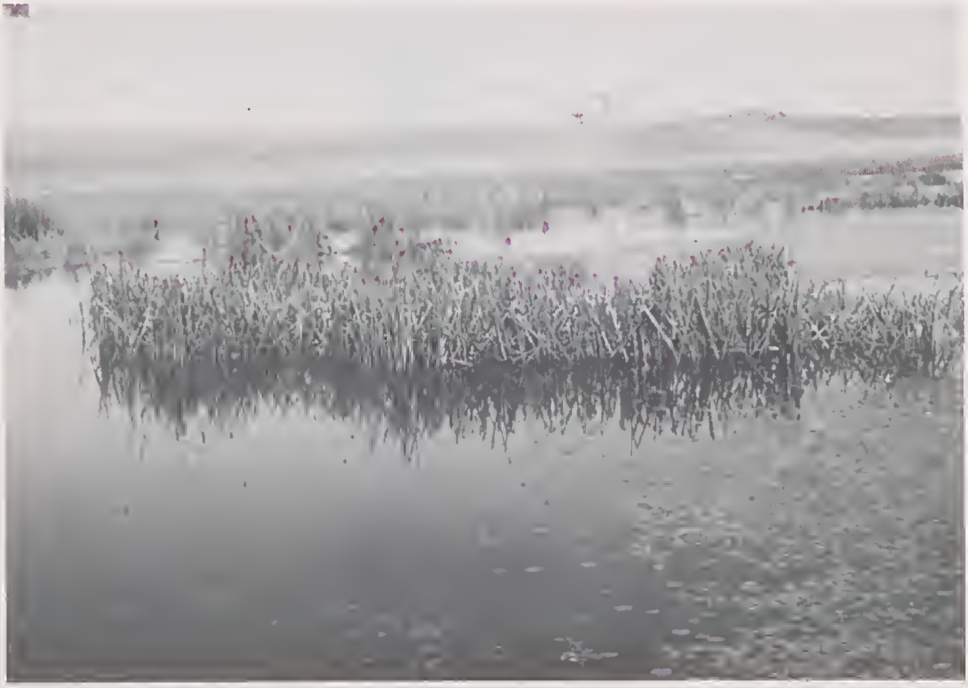

Figure 4. The flora in Weddenjury Lake south of Bombala is grouped into Community 1 and contains several species not recorded in the other communities, including the floating-attached *Nymphoides montana* in the foreground.

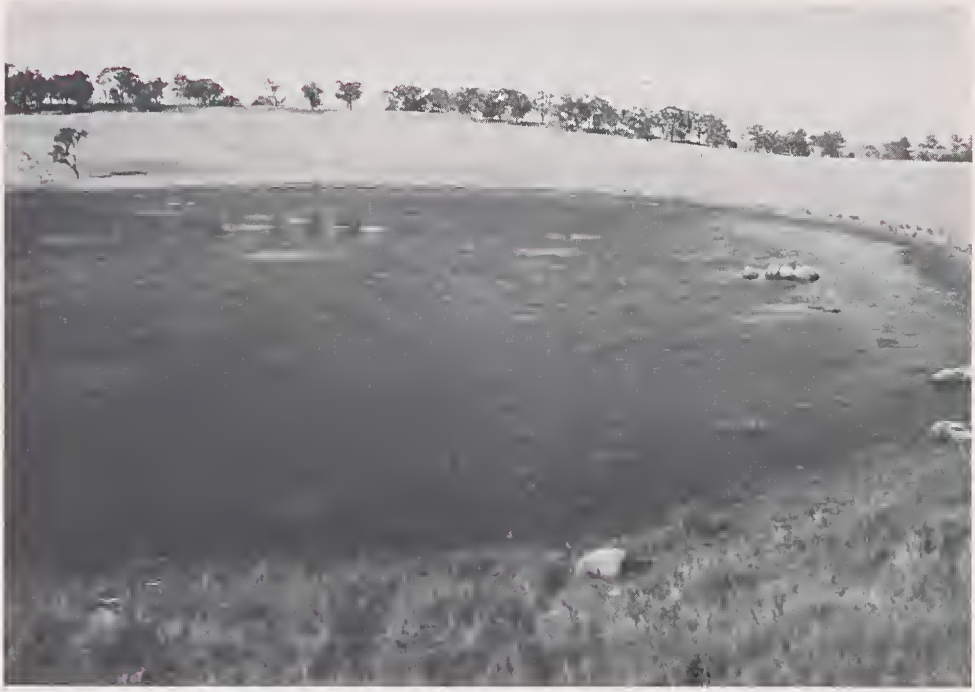

Figure 5. Boundary Lake at Bungarby shown here, and other lakes grouped under plant Community 2, contain abundant emergent, submerged and floating-attached waterplants. They are usually shallow and intermittently dry.

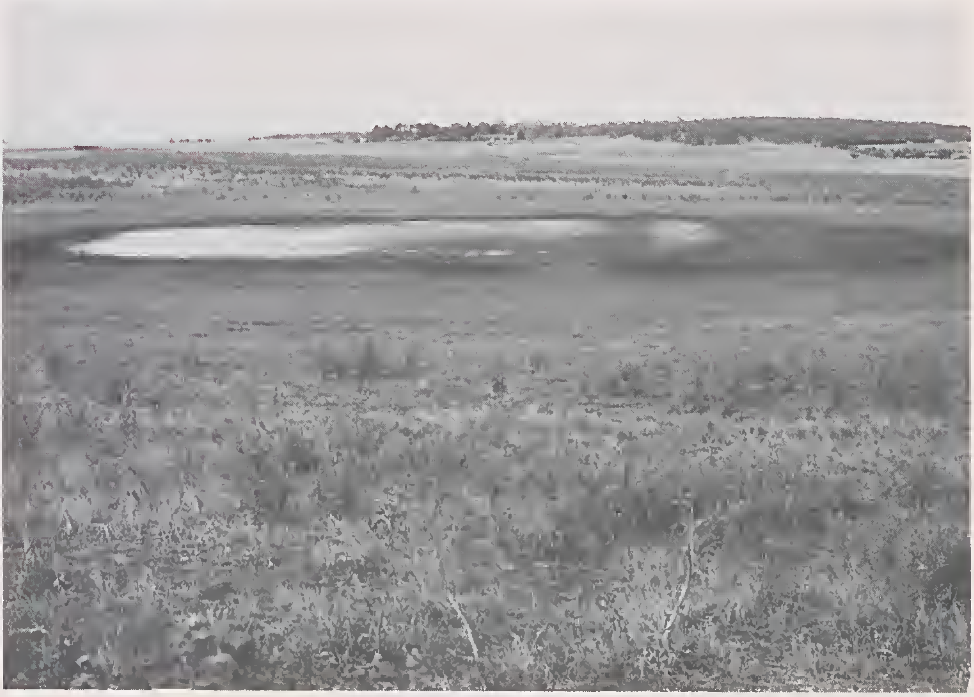

Figure 6. Plant community 3 is often confined to small ephemeral lakes. These contain low numbers of native species, often dominated by *Agrostis avenacea*, and heavily grazed by stock.

Community 3. Shallow ephemeral freshwater herb-grass marsh: *Agrostis avenacea–Centipeda cunninghamii–Eleocharis acuta–Crassula helmsii–Isolepis platycarpa*

Structure: Mid-tall grass layer over sparse ground cover of forbs.

No. samples: 13

Mean lake size: 5 ± 4 ha

Mean no. native sp.: 11 ± 4

Mean no. exotic sp.: 1 ± 2

Dominant species: *Agrostis avenacea*, *Centipeda cunninghamii*, *Eleocharis acuta*, *Crassula helmsii*, *Isolepis platycarpa*, *Limosella australis*, *Persicaria prostrata*.

Indicator species: *Isolepis platycarpa*, *Centipeda cunninghamii*.

Substrate and distribution: Mainly growing on small ephemeral deflation lakes on basalt, ranging in altitude from 740 m to 1080 m. Distributed throughout the study area except for the far western section. (Figure 6.)

Comment: Compared to the other communities, lakes grouped under Community 3 contain an impoverished native flora and a high proportion of exotic plants on the strandline, which is often dominated by the native grass *Agrostis avenacea*. They also were recorded from small to medium sized lakes (median 5 ha) and high altitudes (median 990 m).

Community 4: Deep freshwater sedge-herb marsh: *Carex bichenoviana– Ranunculus diminutus–Lepilaena bilocularis*

Structure: Open sedgeland over a low forbland on the strandline. Submerged waterplants more common than emergent plants in the lakes. Floating-attached waterplants absent. (Figure 7.)

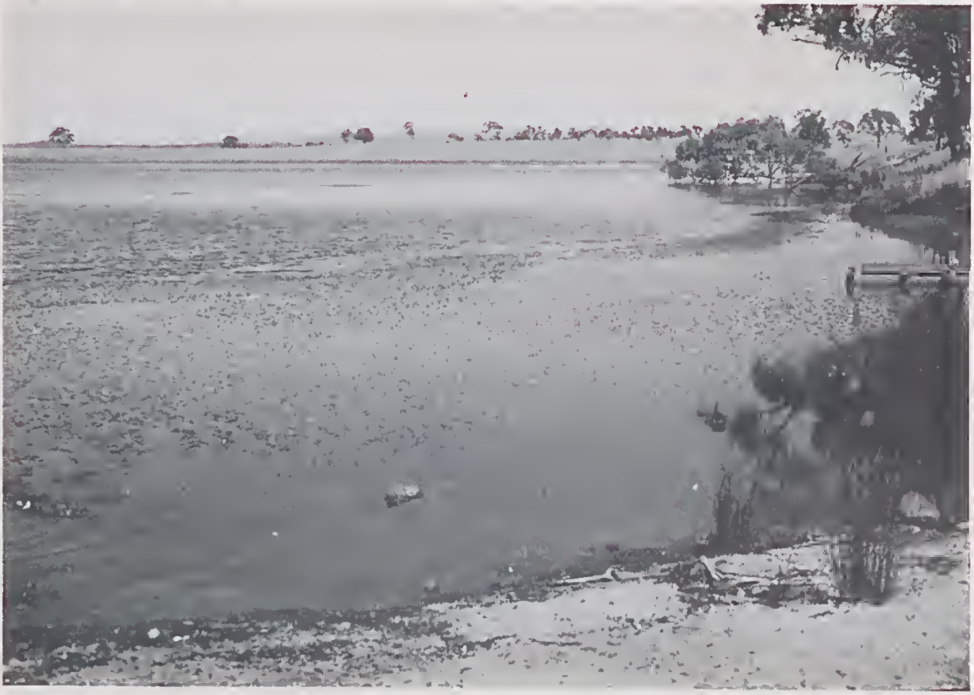

Figure 7. The 36 ha Black Lake is grouped into plant Community 4, which is mainly confined to large perennial lakes, lacks emergent or floating-attached plants, and contains submerged species rare in the other plant communities.

No. samples: 33

Mean lake size: 28 ± 42 ha

Mean no. native sp.: 16 ± 5

Mean no. exotic sp.: 2 ± 1

Dominant species: *Carex bichenoviana–Crassula helmsii–Limosella australis–Ranunculus diminutus–Lepilaena bilocularis.*

Indicator species: *Lepilaena bilocularis, Carex bichenoviana, Schoenoplectus pungens, Myriophyllum verrucosum.*

Substrate and distribution: Predominantly in large deflation or palaeo-lava-blocked lakes distributed throughout the study area on both basalt and granite. Altitude range 750 m to 1160 m. The most conspicuous aspect of the flora in the lakes classified under Community 4 is that they lack floating-attached waterplants and the emergent/submerged *Myriophyllum simulans*, whereas the submerged *Lepilaena bilocularis* is often abundant.

Comment: Lakes grouped under Community 4 contain, on average, lower numbers of native species than lakes grouped under Communities 1 and 2 but greater numbers than lakes grouped under Community 3. Most of the lakes grouped under Community 4 are large (> 10 ha, median 16 ha) but there is a large deviation around the mean of 28 ha.

Environmental determinants

The mean lake size of sites classified into Community 4 are larger than the sites classified under the other three communities. There was, however, no significant correlation at $p < 0.001$ for this conclusion in the GSTA analysis, although a large deviation was derived for lake sizes in Community 4 compared to the other communities. A few small lakes were classified into Community 4 and apparently this limited the degree of significance of the correlation.

The GSTA analysis also found no significant correlation between the distribution of the four communities to either geology or altitude. As mentioned above, several species are restricted to Community 1 at lower altitudes but this fact was not enough to cause the GSTA analysis to significantly correlate Community 1 to a vector that may reflect altitude.

Discussion

The distributions of wetland plants in the lakes on the Monaro are sufficiently varied to allow for the delimitation of four plant communities. These communities, however, share many widely distributed, commonly occurring species, for example *Eleocharis acuta* and *Glossostigma elatinoides*. Such species indicate that the sites shared sufficient characteristics to justify being analysed together. The whole study area was within the geographic distribution of most of the wetland species recorded. There were a number of species with very restricted distributions in the study area (although they are commonly found elsewhere), for example *Ruppia megacarpa, R. polycarpa* and *Villarsia exaltata*. The presence of such species indicated that there could be some benefit from widening the study area in further studies so that wider geographical comparisons of wetland communities can be made.

The data suggest that Community 4 is most distinct from the other communities and there is a trend for this community to be confined to large lakes whereas small lakes could fall into any of the communities.

The distribution of communities 1, 2 and 4 on the Monaro does not appear to be influenced by substrate, since these communities are present in lakes on all the three geological types found in the study area. Higher temperatures and higher rainfall may explain why Community 1 is restricted to the south-eastern edge of the study area. This community shows some similarity in its floristic composition to the wetlands on basalt in the Guyra District of the Northern Tablelands of NSW. Species such as *Nymphoides montana, Glyceria australis* and *Eleocharis sphacelata* grow on the Northern Tablelands (Harden 1990, 1993) and elsewhere but are restricted to Community 1 on the Monaro.

Community 2, which is mainly composed of lakes with high numbers of native species, seems to be composed of small to medium-sized lakes that are shallow but not ephemeral. We expect that these lakes would dry out regularly but would probably fill each winter and stay full for much of the year. In contrast, most of the lakes classified under Community 3 appear to be very shallow and ephemeral. They are probably dry for most of the year and are often dominated by the grass *Agrostis avenacea*. Perhaps many of the plants recorded in the lakes classified under Community 2 cannot survive the drier conditions of the lakes classified under Community 3.

There is a correlation between lake size (and probably depth) and the presence or absence of certain floating-attached and emergent species. The large lakes in Community 4 may lack floating-attached waterplants because they contain stretches of water that are of sufficent length to allow large waves to develop. This wave action may damage plants at the surface and could lead to increased turbidity that would inhibit plant establishment in all but the shallowest sections of a lake. These shallower sections are quickly expanded as water levels drop and are subject to the most extreme wave action. The smaller lakes tend to be shallower than the large lakes and may be less turbid if wave action is minor, therefore a large proportion of the lake-bottom would receive sufficient light for plant growth — encouraging the growth of a greater number of floating-attached and emergent waterplants. *Lepilaena* and other submerged species may survive wave action in these large lakes because they have submerged pollination mechanisms — they can complete their life cycles under water.

Salinity levels in the lakes probably vary over time and between the lakes, though there are few data. As well as possible long-term cycles in salinity levels there may be short-term fluctuations associated with filling and evaporation. Based on our floristic data it appears that some lakes contain a greater proportion of salt-tolerant species than others. The more permanent lakes (which most often are the largest lakes) contain a higher number of salt tolerant species. The larger lakes in Community 4 do not dry out as often as the smaller lakes that were generally grouped under the other communities, therefore salt may accumulate. For example, the 20 ha Kiah Lake, which is situated north of Berridale, has dried out only four times in the last 60 years (J. Allen pers. comm.). Species such as *Lepilaena bilocularis, Myriophyllum verrucosum* and *Carex bichenoviana* may have higher salt tolerance than other species and this could explain their abundance in Community 4 and their rarity in the other communities.

The shape of lakes may also be a factor determining the presence of species. Lakes with gradual slopes and extensive areas of shallows may contain more habitat suitable for the survival of emergent species than those that are steep-sided. Even within the same plant community, variation occurs. Avon Lake (lake 56) and Maffra Lake (lake 35) are grouped into Community 4 on the basis of their shared floristics, yet Avon Lake lacks emergent species and Maffra Lake contains emergent species such as *Schoenoplectus pungens*.

Further research could test some of the hypotheses discussed above about the causes of species distribution in the Monaro lakes (salinity, wave action, lake shape). For example, it may be worth investigating the relationship between salinity, lake size and floristic composition. However, salinity readings that do not record fluctuation within years and between years will not be meaningful.

Conservation, threats and management

At present no wetland on the Monaro is protected either in a conservation reserve or under a conservation management agreement. Most of the wetlands are on private land but some are in travelling stock reserves or are dedicated as water reserves. Some lakes have been cropped or drained. The largest lake on the Monaro, Beards Lake (lake 53), has been drained and is now dry (Figure 8). Most lakes are grazed when water levels are low and pugging of the edges of the lakes by stock may damage the plants.

Although we have no documentation on the pre-European composition of the lakes, many contain a high number of species. This indicates that management of some properties (or sections of them) is compatible with maintaining a range of wetland plant species. Lightly grazed properties, such as 'Quartz Hill' south of Cooma, contain several wetlands grouped under Community 2 that were recorded as being untrampled and rich in species. 'Quartz Hill' relies on native rather than improved pastures and uses less fertilizer than many other properties. We suggest that preventing over-stocking in lake catchments is a key way of limiting the flow of sediments and nutrients into the lakes.

As the majority of lakes are on private land a program aimed at educating landholders about their flora and fauna may be an effective means of ensuring that at least some wetlands are managed sympathetically. Conservation agreements between landholders and a suitable government agency would be a more secure way of protecting a select range of lakes. Such agreements should deal with matters such as limiting cropping on the lake beds, controlling stock access to lakes during periods when the lakes are vulnerable to trampling, and policing illegal game shooting.

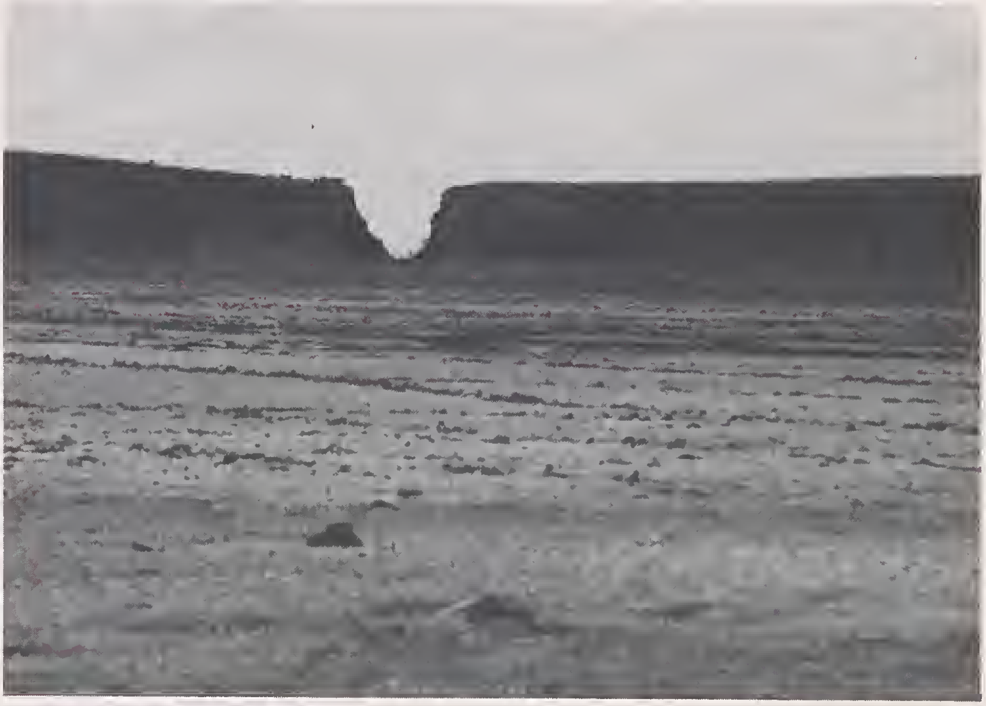

Figure 8. A cut channel through a hill on the western side of Beards Lake has drained the largest lake on the Monaro.

As we did not survey every lake in the study area, selection of lakes for conservation may not have covered all lakes of significance. Based on our data, a number of lakes worthy of protection are listed below. These lakes have been selected because they have a high species richness, contain significant species, are representative of a plant community, or contain few weeds and are not heavily trampled by stock.

- Lake 4: Weddenjury Lake (Figure 4), south of Bombala contains 29 species of native waterplants including several species restricted to this section of the study area (Community 1).
- Lake 149: This lake adjacent to the Cooma–Dalgety Road contains 30 native plant species and lacks signs of trampling at its edge (Community 2).
- Lake 105: Eucumbene Road north east of Jindabyne. 24 native species including *Ottelia ovalifolia*. Lightly grazed (Community 2).
- Lake 35 Maffra Lake: The greater portion of this lake is in a fenced-off travelling stock reserve. This area therefore provides an opportunity for a nature reserve to be dedicated with no cost for land acquisition. This lake contains large stands of the tall sedge *Bolboschoenus caldwellii* which was rarely recorded during the survey (Community 4).
- Lake 30: 'Snowleigh' near Bungarby. This lake appeared to be undisturbed by stock and had a relative species-rich flora (Community 4).
- Lake 46: 'Peters Park'. This lake was not pugged by stock and contained a high number of species (28 species) (Community 4).
- Lake 92: Carrolls Lake. This lake was fenced-off from stock and contained a large number of waterbirds (Community 4).

A number of other lakes in Community 2 could be considered for protection as they were recorded as being in a sound condition. All of the lakes in Community 3 contain few species and were heavily pugged by stock. Therefore none are recommended for conservation.

Surveys of other lakes in the study area may lead to further proposals for conservation, although the bulk of the unsampled lakes are small, ephemeral, and heavily disturbed and it is unlikely that these would contain features worthy of protection.

Acknowledgements

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Appendix 1. Name, location, size, permanence, altitude, substrate and plant communities of the Monaro lakes, New South Wales

LP = lake permanence (p = permanent (rarely dry), I = intermittent (seasonally dry), E = ephemeral (occasionally full) assigned to each lake sampled

Sub. = substrate (Tb = Tertiary basalt, G = granitic rocks, S = sedimentary and meta-sedimentary rocks)

NA = not assessed; * = lake sampled

Lake no.	Lake name	Map sheet	Grid reference	Size (ha)	LP	Alt. (m)	Sub.	Plant comm.
1		Craigie 100 000	698500 5898800	2	NA	760	G	NA
2		Craigie 100 000	700500 5899200	2	NA	760	G	NA
3*	Green Lake	Craigie 100 000	701100 5899800	3	I	760	G	1
4*	Weddenjerry Lake	Craigie 100 000	700600 5900600	5	I	760	G	1
5*		Coolumbooka 25 000	705200 5915100	6	I	830	Tb	1
6	High Lake	Coolumbooka 25 000	702000 5916000	3	NA	850	Tb	NA
7*		Bukalong 25 000	689300 5921400	2	E	740	Tb	3
8		Bukalong 25 000	689400 5921600	1	NA	750	Tb	NA
9		Bukalong 25 000	690600 5921300	1	NA	750	Tb	NA
10		Bukalong 25 000	692400 5922700	2	NA	860	Tb	NA
11		Bukalong 25 000	690500 5924200	2.5	NA	870	Tb	NA
12		Bukalong 25 000	691200 5924200	3	NA	860	Tb	NA
13		Bukalong 25 000	692100 5924800	5.5	NA	880	Tb	NA
14		Bukalong 25 000	693000 5926100	3	NA	830	Tb	NA
15		Bukalong 25 000	699400 5925500	3	NA	870	Tb	NA
16		Bukalong 25 000	699200 5925700	2	NA	870	Tb	NA
17		Bukalong 25 000	691000 5928700	2	NA	760	Tb	NA
18		Bukalong 25 000	695700 5929800	1	NA	850	Tb	NA
19		Bukalong 25 000	696000 5930200	6.5	NA	850	Tb	NA
20		Bukalong 25 000	700400 5929600	2	NA	920	Tb	NA
21*		Bukalong 25 000	700700 5930000	4	NA	890	Tb	2
22	Green Lake	Cathcart 25 000	705500 5919500	11	NA	820	Tb	NA
23*	Black Lake	Cathcart 25 000	706100 5919900	36	P	820	Tb	4

Appendix 1. (cont.)

Lake no.	Lake name	Map sheet	Grid reference	Size (ha)	LP	Alt. (m)	Sub.	Plant comm.
24		Cathcart 25 000	701500 5923900	4	NA	820	S	NA
25*		Cathcart 25 000	701300 5930100	3	I	880	Tb	4
26*		Thredbo 50 000	632700 5940100	1	I	1170	G	2
27		Numbla Vale 50 000	666600 5938000	5	NA	800	G	NA
28		Numbla Vale 50 000	677800 5937900	4	NA	920	Tb	NA
29		Numbla Vale 50 000	677500 5938200	5	NA	920	Tb	NA
30*		Numbla Vale 50 000	677800 5938700	16	P	920	Tb/G	4
31		Numbla Vale 50 000	678600 5938500	7	NA	940	Tb	NA
32*		Numbla Vale 50 000	634300 5944500	1	I	1040	G	2
33*	Lake Jillamatong	Numbla Vale 50 000	642000 5956500	37	P	1100	G	4
34		Numbla Vale 50 000	678700 5953300	9	NA	880	Tb	NA
35*	Maffra Lake	Numbla Vale 50 000	678000 5953500	23	P	890	Tb/G	4
36		Numbla Vale 50 000	678500 5954800	4	NA	880	Tb	NA
37		Numbla Vale 50 000	678900 5954600	6	NA	880	Tb	NA
38	Burns Lakes	Wangellic 25 000	692800 5938100	5	NA	930	Tb	NA
39	Burns Lakes	Wangellic 25 000	693800 5938200	2	NA	930	Tb	NA
40*	Burns Lakes	Wangellic 25 000	693500 5938900	26	P	920	Tb	4
41	Barkers Lake	Wangellic 25 000	679700 5935500	3	NA	890	Tb	NA
42		Wangellic 25 000	679200 5937600	4	NA	930	Tb	NA
43*	Island Lake	Wangellic 25 000	679200 5938700	15	I	960	Tb	4
44		Wangellic 25 000	679200 5939600	3.5	NA	940	Tb	NA
45		Wangellic 25 000	679000 5940100	5	NA	950	Tb	NA
46*		Wangellic 25 000	680400 5939900	20	P	930	Tb	4
47*		Wangellic 25 000	681900 5940400	11	I	940	Tb	4
48*	Boundary Line	Wangellic 25 000	679600 5941100	4	I	960	Tb/G	2

Appendix 1. (cont.)

Lake no.	Lake name	Map sheet	Grid reference	Size (ha)	LP	Alt. (m)	Sub.	Plant comm.
49		Wangellic 25 000	681900 5941100	2	NA	970	Tb	NA
50*		Wangellic 25 000	683300 5941200	14	I	960	Tb	3
51		Wangellic 25 000	682300 5941700	3	NA	960	Tb	NA
52	Washpool Lake	Wangellic 25 000	680900 5941700	5	NA	950	Tb	NA
53*	Beards Lake	Wangellic 25 000	681700 5943000	215	E	950	Tb	4
54		Wangellic 25 000	684100 5943500	4	NA	960	Tb	NA
55*		Glen Allen 25 000	702700 5933100	5	I	920	Tb	3
56*	Avon Lake	Teapot & Wangellic 25 000	683100 5945300	117	P	950	Tb	4
57		Teapot 25 000	684100 5945600	3	NA	930	Tb	NA
58	Dukes Lake	Teapot 25 000	684300 5947000	24	NA	960	Tb	NA
59		Teapot 25 000	686200 5947100	6	NA	1000	Tb	NA
60		Teapot 25 000	684600 5948600	21	NA	970	Tb	NA
61		Teapot 25 000	684000 5948800	2	NA	970	Tb	NA
62*		Teapot 25 000	686600 5949400	2	I	990	Tb	2
63		Teapot 25 000	683900 5950500	4	NA	950	Tb	NA
64*		Teapot 25 000	683500 5952900	6	I	920	Tb	4
65		Teapot 25 000	685800 5951700	12	NA	930	Tb	NA
66		Teapot 25 000	687600 5951600	4	NA	960	Tb	NA
67		Teapot 25 000	687900 5951900	3	NA	970	Tb	NA
68*	Boundary Lake	Teapot 25 000	689600 5954000	8	I	990	Tb	4
69*	Coopers Lake	Teapot 25 000	691400 5954700	19	P	980	Tb	4
70*		Teapot 25 000	694900 5956600	1	I	1000	Tb	4
71		Teapot 25 000	700000 5956000	1	NA	1090	Tb	NA
72		Teapot 25 000	699800 5956200	2	NA	1100	Tb	NA
73		Teapot 25 000	700300 5956400	1	NA	1100	Tb	NA

Appendix 1. (cont.)

Lake no.	Lake name	Map sheet	Grid reference	Size (ha)	LP	Alt. (m)	Sub.	Plant comm.
74		Nimmitabel 25 000	702900 5948500	2	NA	1020	Tb	NA
75		Nimmitabel 25 000	702500 5951600	1	NA	1080	Tb	NA
76*	Buckleys Lake	Berridale 50 000	674400 5963900	40	P	980	Tb/G	4
77*		Berridale 50 000	675800 5963800	2	E	960	Tb	3
78		Berridale 50 000	675600 795964900	1	NA	940	Tb	NA
79N		Berridale 50 000	677000 5966900	1	NA	900	Tb	NA
79S		Berridale 50 000	677000 5966800	1	NA	900	Tb	NA
80		Berridale 50 000	676600 5966900	1.5	NA	900	Tb	NA
81		Berridale 50 000	676400 5967100	1	NA	900	Tb	NA
82		Berridale 50 000	676000 5967800	3	NA	900	Tb	NA
83		Berridale 50 000	676400 5967700	1.5	NA	900	Tb	NA
84		Berridale 50 000	676700 5967700	2	NA	900	Tb	NA
85		Berridale 50 000	677200 5967900	3	NA	900	Tb	NA
86		Berridale 50 000	676400 5968100	2	NA	920	Tb	NA
87		Berridale 50 000	676200 5968400	1	NA	940	Tb	NA
88		Berridale 50 000	677800 5968700	3	NA	920	Tb	NA
89		Berridale 50 000	671000 5970500	1	NA	820	Tb	NA
90*	Coolamatong Lake	Berridale 50 000	660100 5972600	41	P	900	S	4
91		Berridale 50 000	670300 5973300	1	NA	840	Tb	NA
92*	Carrolls Lake	Berridale 50 000	670600 5974000	5	I	840	Tb/G	4
93*	Salt Lake	Berridale 50 000	675200 5973700	10	P	900	Tb/G	4
94		Berridale 50 000	675900 5974000	1	NA	900	Tb	NA
95		Berridale 50 000	669500 5975000	1	NA	860	Tb	NA
96		Berridale 50 000	669500 5975200	1	NA	860	Tb	NA
97		Berridale 50 000	670500 5975600	1	NA	860	Tb/G	NA

Appendix 1. (cont.)

Lake no.	Lake name	Map sheet	Grid reference	Size (ha)	LP	Alt. (m)	Sub.	Plant comm.
98		Berridale 50 000	674100 5975100	1	NA	900	Tb/G	NA
99		Berridale 50 000	674400 5975000	1	NA	900	Tb	NA
100		Berridale 50 000	675100 5974800	1	NA	900	Tb	NA
101		Berridale 50 000	675700 5974500	1	NA	900	Tb	NA
102*	Kiah	Berridale 50 000	660300 5977900	20	P	900	S	4
103		Berridale 50 000	670100 5977500	4	NA	860	G	NA
104*	Lake Bullenbalong	Berridale 50 000	651700 5979500	19	P	1140	G	4
105*		Berridale 50 000	649800 5980700	3	I	1160	G	2
106*	Hugundara Lagoon	Berridale 50 000	660900 5983200	6	I	980	G	4
107*		Berridale 50 000	661100 5985400	1	I	1080	G	2
108	Wishing Lake	Berridale	670100 5982700	2	NA	1040	Tb	NA
109		Berridale 50 000	670500 5982900	1	NA	1060	Tb	NA
110*		Berridale 50 000	670500 5983400	2	I	1060	Tb	2
111		Berridale 50 000	668500 5984100	3	NA	1060	Tb	NA
112*	Cootralantra Lake	Berridale 50 000	669700 5985100	95	P	1040	TB/G	4
113		Berridale 50 000	672800 5982900	1	NA	1040	Tb	NA
114		Berridale 50 000	673600 5982800	1	NA	1020	Tb	NA
115*		Berridale 50 000	673000 5983300	1	I	1040	Tb	2
116*	Killmacoola Lagoon	Berridale 50 000	673000 5983800	24	P	1000	G	4
117		Berridale 50 000	675100 5983800	2	NA	1000	Tb	NA
118		Berridale 50 000	672300 5984100	1	NA	1040	Tb	NA
119N		Berridale 50 000	672100 5984600	0.5	NA	1040	Tb	NA
119S		Berridale 50 000	672200 5984400	1	NA	1040	Tb	NA
120		Berridale 50 000	672200 5985100	2	NA	1040	Tb	NA

Appendix 1. (cont.)

Lake no.	Lake name	Map sheet	Grid reference	Size (ha)	LP	Alt. (m)	Sub.	Plant comm.
121		Berridale 50 000	673200 5985200	11	NA	1040	Tb	NA
122		Berridale 50 000	674300 5985200	2	NA	1040	Tb	NA
123		Berridale 50 000	674700 5985500	3	NA	1040	S	NA
124		Berridale 50 000	674900 5985800	3	NA	1040	S	NA
125		Myalla 25 000	694900 5961800	2	NA	1080	Tb	NA
126		Myalla 25 000	681800 5963800	3	NA	990	Tb	NA
127		Myalla 25 000	688800 5963900	0.5	NA	1040	Tb	NA
128		Myalla 25 000	689100 5964300	4.5	NA	1030	Tb	NA
129		Myalla 25 000	698700 5963300	3	NA	1090	Tb	NA
130*		Myalla 25 000	700600 5964100	6	I	1050	Tb	4
131		Myalla 25 000	695300 596500	1	NA	1100	Tb	NA
132		Myalla 25 000	697200 5965300	1	NA	1020	Tb	NA
133		Myalla 25 000	700000 5964900	1.5	NA	1060	Tb	NA
134		Myalla 25 000	686200 5967300	1.5	NA	1080	Tb	NA
135		Myalla 25 000	686900 5966900	2	NA	1080	Tb	NA
136		Myalla 25 000	687400 5966800	4	NA	1080	Tb	NA
137		Myalla 25 000	687000 5967300	4	NA	1080	Tb	NA
138		Myalla 25 000	688800 5967800	1	NA	1110	Tb	NA
139		Myalla 25 000	690100 5968200	2	NA	1100	Tb	NA
140*		Myalla 25 000	697100 5966900	9	E	1000	Tb	3
141*		Myalla 25 000	698100 5966500	6	I	1020	Tb	2
142		Myalla 25 000	698300 5966700	3	NA	1000	Tb	NA
143		Myalla 25 000	700700 5966100	2.5	NA	1020	Tb	NA
144		Myalla 25 000	683200 5969300	1.5	NA	1040	Tb	NA

Appendix 1. (cont.)

Lake no.	Lake name	Map sheet	Grid reference	Size (ha)	LP	Alt. (m)	Sub.	Plant comm.
145		Myalla 25 000	681600 5970100	2	NA	1030	Tb	NA
146		Myalla 25 000	683300 5970100	3	NA	1040	Tb	NA
147		Myalla 25 000	684600 5970200	12	NA	1020	Tb	NA
148		Myalla 25 000	686700 5970100	7	NA	1040	Tb	NA
149*		Myalla 25 000	683500 5970500	7	I	1020	Tb	2
150		Myalla 25 000	684500 5970600	16	NA	1020	Tb	NA
151		Myalla 25 000	691300 5969900	2	NA	1090	Tb	NA
152		Myalla 25 000	700100 5968400	6	NA	1000	Tb	NA
153		Myalla 25 000	700900 5968500	1	NA	990	Tb	NA
154*		Myalla 25 000	700700 5969200	8	E	1000	Tb	3
155*		Myalla 25 000	683400 5971400	2	I	1020	Tb	2
156		Myalla 25 000	686100 5971400	16	NA	1020	Tb	NA
157		Myalla 25 000	687500 5971300	2	NA	1050	Tb	NA
158		Myalla 25 000	701000 5970900	4.5	NA	1000	Tb	NA
159		Myalla 25 000	701700 5970800	2	NA	980	Tb	NA
160		Myalla 25 000	701400 5971700	3	NA	990	Tb	NA
161		Myalla 25 000	682700 5972300	4.5	NA	1010	Tb	NA
162*	Racecourse Lake	Kydra 25 000	703300 5958400	6	I	1090	Tb	2
163		Kydra 25 000	701900 5959500	1	NA	1090	Tb	NA
164		Jillimatong 25 000	681600 5972500	2	NA	1020	S	NA
165		Jillimatong 25 000	683300 5972700	7	NA	1010	Tb	NA
166*		Jillimatong 25 000	683900 5972700	6	I	1000	Tb	3
167*		Jillimatong 25 000	683500 5973400	1.5	I	1020	Tb	2
168		Jillimatong 25 000	694100 5974300	3	NA	990	Tb	NA

Appendix 1. (cont.)

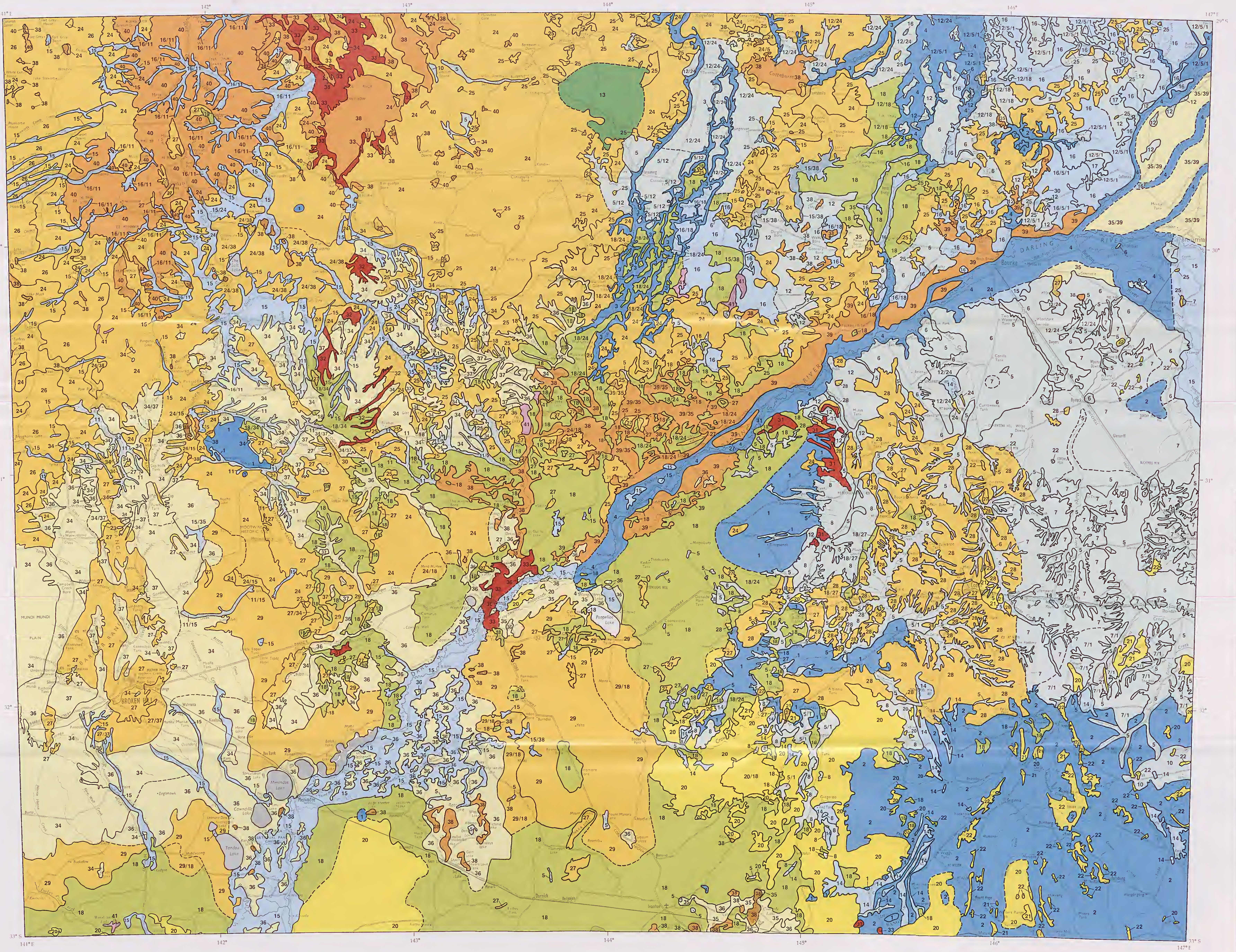
Lake no.	Lake name	Map sheet	Grid reference	Size (ha)	LP	Alt. (m)	Sub.	Plant comm.
169		Jillimatong 25 000	684600 5974700	2	NA	960	Tb	NA
170		Jillimatong 25 000	684300 5974900	13	NA	960	Tb	NA
171*	Green Lake	Jillimatong 25 000	680400 5975400	3	I	990	Tb	3
172*	Arable Lake	Jillimatong 25 000	682100 5975600	16	P	980	Tb	4
173*		Jillimatong 25 000	684200 5976300	5	I	900	Tb	3
174		Jillimatong 25 000	684500 5976800	6	NA	950	Tb	NA
175		Jillimatong 25 000	685000 5977000	2	NA	940	Tb	NA
176		Jillimatong 25 000	687700 5976700	2	NA	980	Tb	NA
177		Jillimatong 25 000	687600 5976900	2	NA	980	Tb	NA
178*		Jillimatong 25 000	681400 5977400	4	I	1080	Tb	3
179		Jillimatong 25 000	689100 5977700	2	NA	930	Tb	NA
180		Jillimatong 25 000	696800 5977700	1.5	NA	930	Tb	NA
181	Tinkers Lake	Jillimatong 25 000	680600 5978300	0.5	NA	1000	Tb	NA
182		Jillimatong 25 000	683300 5977900	1.5	NA	920	Tb	NA
183		Jillimatong 25 000	682700 5978500	1.5	NA	950	Tb	NA
184		Jillimatong 25 000	686700 5978400	4	NA	920	Tb	NA
185		Jillimatong 25 000	687600 5978600	1.5	NA	920	Tb	NA
186		Jillimatong 25 000	687500 5978900	12	NA	920	Tb	NA
187		Jillimatong 25 000	686600 5979500	3	NA	920	Tb	NA
188		Jillimatong 25 000	690500 5979600	1	NA	920	G	NA
189		Jillimatong 25 000	684100 5979900	6	NA	930	Tb	NA
190*		Jillimatong 25 000	684700 5980100	4	I	940	Tb	4
191		Jillimatong 25 000	683800 5980600	2	NA	950	Tb	NA
192*		Jillimatong 25 000	684400 5980500	15	P	940	Tb	4

Appendix 1. (cont.)

Lake no.	Lake name	Map sheet	Grid reference	Size (ha)	LP	Alt. (m)	Sub.	Plant comm.
193		Jillimatong 25 000	694400 5981300	4	NA	920	Tb	NA
194*	Thurbergal Lake	Jillimatong 25 000	701000 5982400	7	I	870	Tb	4
195*		Jillimatong 25 000	681600 5983100	1	E	900	Tb	3
196		Jillimatong 25 000	682500 5983600	1	NA	920	Tb	NA
197		Jillimatong 25 000	694700 5983400	2	NA	880	Tb	NA
198		Jillimatong 25 000	682200 5985200	2	NA	910	Tb	NA
199*		Eucumbene 50 000	666900 5988600	1	I	1220	G	2
200*		Eucumbene 50 000	671900 5988200	4	P	1000	Tb	2
201		Eucumbene 50 000	672800 5988400	4	NA	1000	Tb	NA
202		Eucumbene 50 000	676800 5991100	7	NA	910	Tb	NA
203		Eucumbene 50 000	676200 5993300	4	NA	980	Tb	NA
204		Eucumbene 50 000	675500 6003300	2	NA	1200	Tb	NA
205		Eucumbene 50 000	670700 6004200	1	NA	1140	Tb	NA
206	Long Lake	Eucumbene 50 000	67130 6004600	15	NA	1140	Tb	NA
207*	Rocky Lake	Eucumbene 50 000	674800 6004400	6	I	1160	Tb	4
208*	O'Neills Lagoon	Eucumbene 50 000	672800 6005400	18	P	1120	Tb	4
209		Cooma 25 000	694300 5987800	3	NA	850	Tb	NA
210*	Muddah Lake	Murrumbucca 25 000	684000 6002100	18	P	1000	Tb	4
211		Murrumbucca 25 000	686200 6002200	1.5	NA	1000	Tb	NA
212*		Murrumbucca 25 000	685800 6002500	2	E	1000	Tb	3
213*		Murrumbucca 25 000	684400 6003400	5	E	1010	Tb	3
214		Murrumbucca 25 000	686000 6003700	1.5	NA	1010	Tb	NA
215*	Bullanamang Lake	Murrumbucca 25 000	690400 6013500	4	I	750	G	4

NATURAL VEGETATION OF NORTH WESTERN NEW SOUTH WALES

1 : 1 000 000



OPEN-FOREST

🟦

White Cypress Pine communities (see also 14)

1	*Callitris glaucophylla* on sand
2	*Callitris glaucophylla - Eucalyptus intertexta*

Yapunyah communities

3	*Eucalyptus ochrophloia*

Coolibah communities

4	*Eucalyptus coolabah* subsp. *coolabah*

WOODLAND

⬜

Bimble Box communities

5	*Eucalyptus populnea* subsp. *bimbil*
5/1	*Eucalyptus populnea* subsp. *bimbil - Callitris glaucophylla*
5/12	*Eucalyptus populnea* subsp. *bimbil - Acacia excelsa*
6	*Eucalyptus populnea* subsp. *bimbil - Acacia aneura - Acacia spp.*
7	*Eucalyptus populnea* subsp. *bimbil - Eucalyptus intertexta*
7/1	*Eucalyptus populnea* subsp. *bimbil - Eucalyptus intertexta - Callitris glaucophylla*

Red Box communities

8	*Eucalyptus intertexta - Acacia aneura*

Silver-leaved Ironbark communities

9	*Eucalyptus melanophloia - Triodia mitchellii* var. *breviloba*

Western Grey Box communities

10	*Eucalyptus microcarpa* (narrow-leaved race)

River Red Gum communities

11	*Eucalyptus camaldulensis*
11/5	*Eucalyptus camaldulensis - Eucalyptus populnea* subsp. *bimbil*
11/15	*Eucalyptus camaldulensis - Eucalyptus largiflorens*

Ironwood communities

12	*Acacia excelsa*
12/5/1	*Acacia excelsa - Eucalyptus populnea* subsp. *bimbil - Callitris glaucophylla*
12/18	*Acacia excelsa - Casuarina pauper - Alectryon oleifolius*
12/24	*Acacia excelsa - Acacia aneura*

OPEN-WOODLAND

🟩

Inland Bloodwood - Bimble Box communities

13	*Eucalyptus* aff. *terminalis - Eucalyptus populnea* subsp. *bimbil*

LOW OPEN-FOREST

🟦

Cypress Pine communities (see also 1)

14	*Callitris glaucophylla*

Black Box communities

15	*Eucalyptus largiflorens*
15/24	*Eucalyptus largiflorens - Acacia aneura*
15/35	*Eucalyptus largiflorens - Atriplex vesicaria*
15/38	*Eucalyptus largiflorens - Eragrostis australasica - Muehlenbeckia florulenta*

Gidgee communities

16	*Acacia cambagei*
16/5/1	*Acacia cambagei - Eucalyptus populnea* subsp. *bimbil - Callitris glaucophylla*
16/11	*Acacia cambagei - Eucalyptus camaldulensis*
16/18	*Acacia cambagei - Casuarina cristata - Alectryon oleifolius*

Brigalow communities

17	*Acacia harpophylla*

LOW WOODLAND

🟩

Belah - Rosewood communities

18	*Casuarina pauper - Alectryon oleifolius*
18/12	*Casuarina pauper - Alectryon oleifolius - Acacia excelsa*
18/24	*Casuarina pauper - Alectryon oleifolius - Acacia aneura*
18/34	*Casuarina pauper - Alectryon oleifolius - Atriplex vesicaria*

Inland Bloodwood - Whitewood communities

19	*Eucalyptus* aff. *terminalis - Atalaya hemiglauca*

TALL SHRUBLAND

🟨

Mallee communities

20	*Eucalyptus socialis* Red Mallee, on sand plain
20/18	*Eucalyptus socialis - Casuarina pauper - Alectryon oleifolius*
21	*Eucalyptus socialis* Red Mallee, on rocky hills
22	*Eucalyptus vicina*
23	*Eucalyptus gillii* Curly Mallee

TALL SHRUBLAND

🟨

Mulga communities

24	*Acacia aneura*, on sand plain
24/5	*Acacia aneura - Eucalyptus populnea* subsp. *bimbil*
24/15	*Acacia aneura - Eucalyptus largiflorens*
24/16	*Acacia aneura - Acacia cambagei*
24/38	*Acacia aneura - Eragrostis australasica - Muehlenbeckia florulenta*
25	*Acacia aneura*, on rocky hills
26	*Acacia aneura - Acacia ligulata*
26/38	*Acacia aneura - Acacia ligulata - Eragrostis australasica - Muehlenbeckia florulenta*
27	*Acacia aneura - Acacia tetragonophylla*
27/34	*Acacia aneura - Acacia tetragonophylla - Atriplex vesicaria*
27/37	*Acacia aneura - Acacia tetragonophylla - Maireana sedifolia*
28	*Acacia aneura - Acacia excelsa - Geijera parviflora*

Other Acacia Shrubland communities

29	*Acacia loderi* Nelia
29/18	*Acacia loderi - Casuarina pauper - Alectryon oleifolius*
30	*Acacia clivicola* Bastard Mulga

SHRUBLAND

🟥

31	*Acacia ramulosa* Horse Mulga
32	*Acacia cana* Cabbage-tree Wattle

Old Man Saltbush communities

33	*Atriplex nummularia*

DWARF OPEN-SCRUB

🟨

Saltbush and Bluebush communities

34	*Atriplex vesicaria* Bladder Saltbush, on downs & hills
34/37	*Atriplex vesicaria - Maireana sedifolia*
35	*Atriplex vesicaria* Bladder Saltbush, on floodplains
35/39	*Atriplex vesicaria - Astrebla lappacea* on floodplains
36	*Maireana sedifolia* Pearl Bluebush on sandplain
37	*Maireana sedifolia* Pearl Bluebush on rocky areas

HERBLAND

🟧

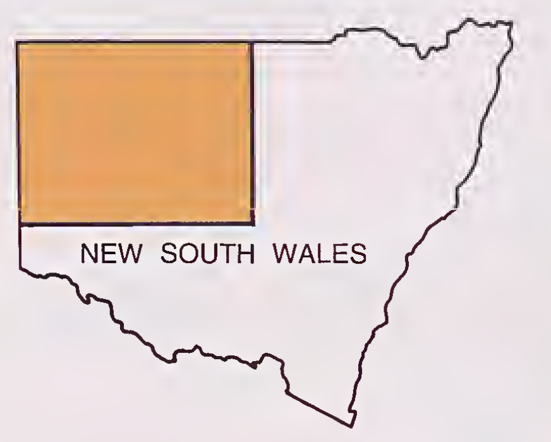
Grassland communities

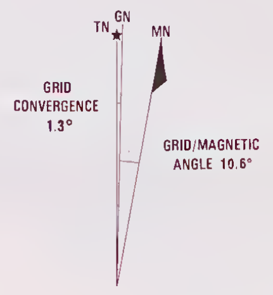
38	*Eragrostis australasica - Muehlenbeckia florulenta* Canegrass - Lignum
39	*Astrebla lappacea* Curly Mitchell Grass, on floodplain
39/35	*Astrebla lappacea - Atriplex vesicaria*
40	*Astrebla* spp. Mitchell Grasses, on downs

SALT LAKES

🟪

41	Various herb communities on margins





SCALE 1:1 000 000

VEGETATION BOUNDARIES Definite ———————

Approximate – – – – – – –

Topographic base from north-western New South Wales 1:1 000 000 map is Crown Copyright and has been reproduced with the permission of the Land Information Centre, Bathurst.

MILPARINKA	URISINO	YANTABULLA	ENNGONIA
COBHAM LAKE	WHITE CLIFFS	LOUTH	BOURKE
BROKEN HILL	WILCANNIA	BARNATO	COBAR
MENINDEE	MANARA	IVANHOE	NYMAGEE

Key to 1:250 000 map sheet areas

The map shows original vegetation cover before European settlement, as interpreted from aerial photography and field survey. Present vegetation has been affected by widespread grazing and localised clearing

NATURAL VEGETATION
OF
NORTH WESTERN
NEW SOUTH WALES
(1:1 000 000)

Mapped by John Pickard from field traverses
1969-1981, geological maps, air photographs,
photomosaics & existing vegetation maps.

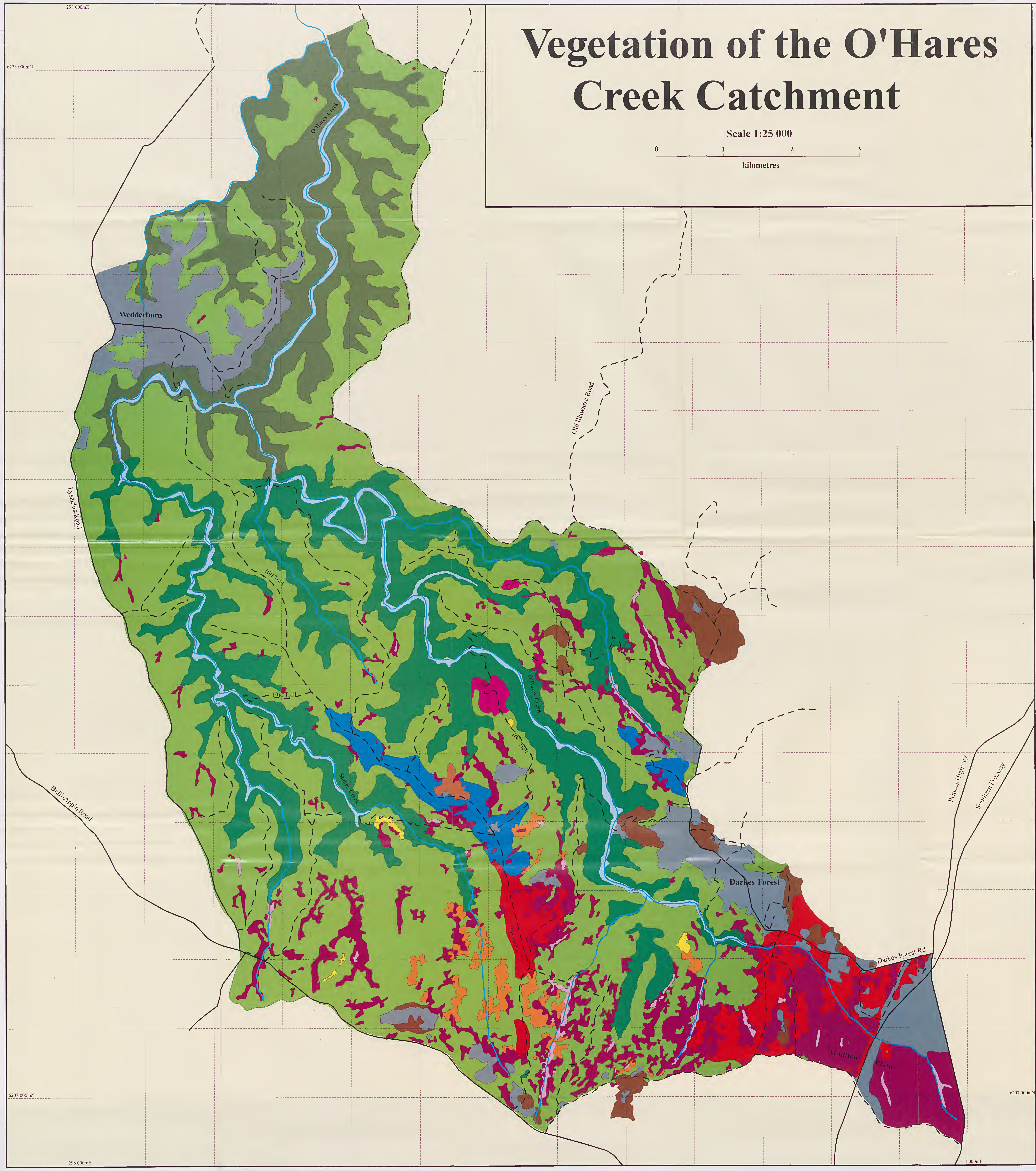
Detailed descriptions of the plant
communities are given in
Pickard, J & Norris, E.H. (1994)
CUNNINGHAMIA Volume 3 Number 3.

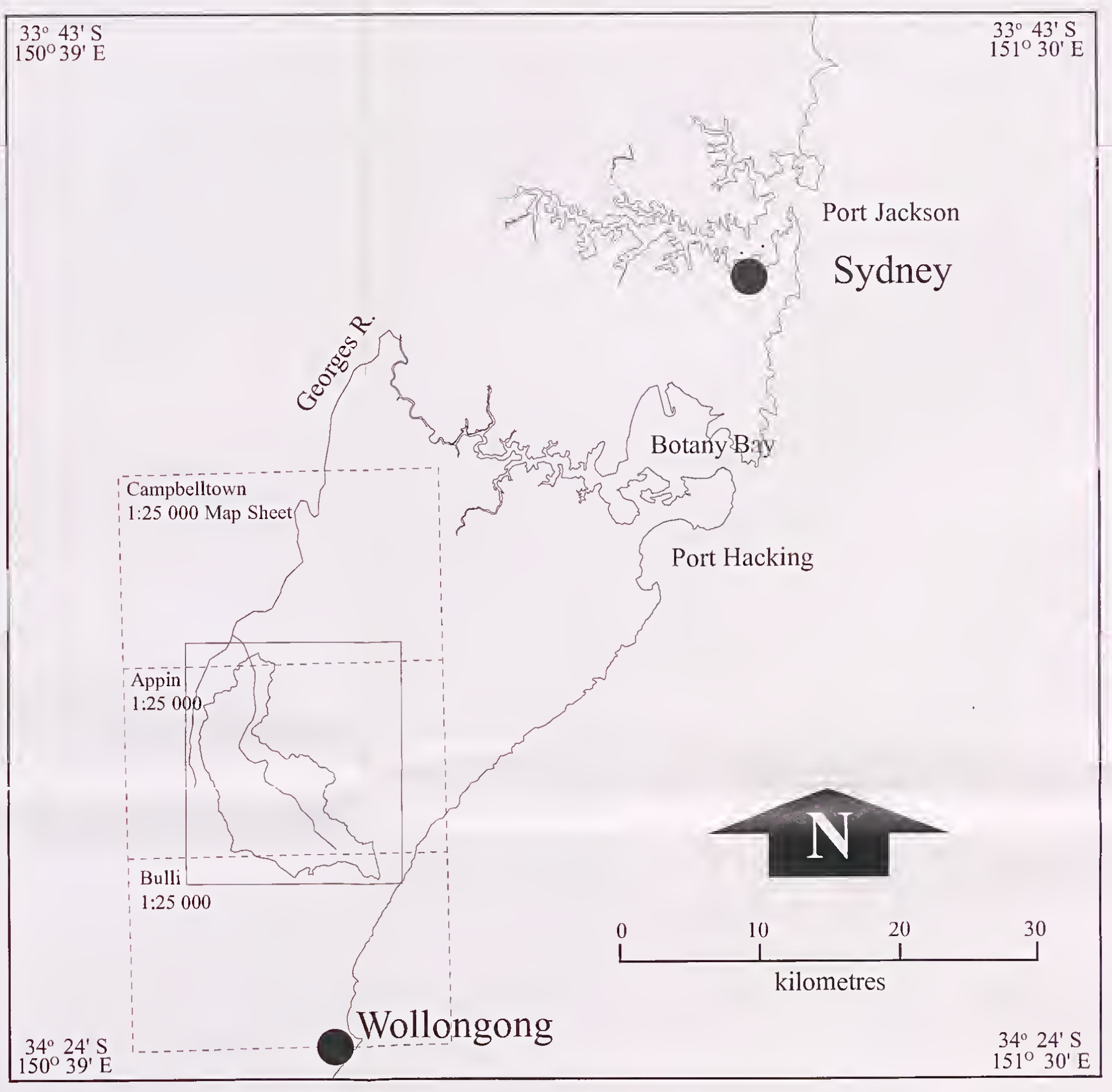
Compiled & prepared at the
NATIONAL HERBARIUM OF NEW SOUTH WALES
ROYAL BOTANIC GARDENS SYDNEY (1994)

Understanding the ecology of our native plants

Vegetation of the O'Hares Creek Catchment

Scale 1:25 000

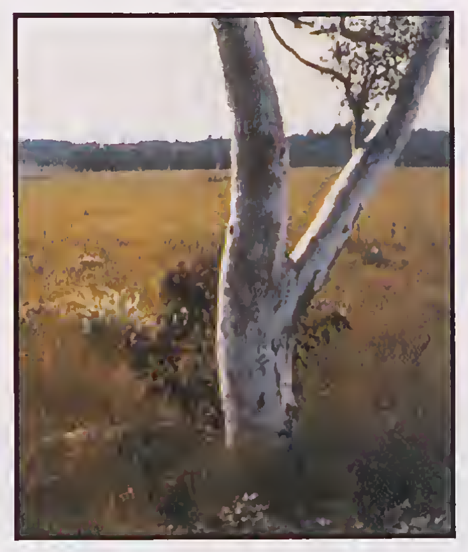




Community	Map Symbol	Main Species	Habitat
Shale Forest (SF)	🟫	*Eucalyptus globoidea, Angophora costata, Eucalyptus piperita, Eucalyptus gummifera*	Flat ridgetops capped with Hawkesbury Shale
Western Gully Forest (WGF)	🟩	*Eucalyptus punctata, Eucalyptus pilularis, Eucalyptus agglomerata, Angophora costata*	Gullies and slopes on Hawkesbury Sandstone in low rainfall areas
Eastern Gully Forest (EGF)	🟩	*Eucalyptus piperita, Angophora costata, Eucalytus gummifera*	Gullies and slopes on Hawkesbury Sandstone in high rainfall areas
Riparian Scrub (RS)	🟦	*Tristaniopsis laurina, Tristania neriifolia, Leptospermum morrisonii*	Sandy alluvium along major creek lines
Ironstone Woodland (IW)	🟥	*Eucalyptus sieberi, Eucalyptus racemosa, Eucalyptus gummifera*	Broad well-drained ridgetops with ironstone mantle on Hawkesbury Sandstone
Sandstone Woodland (SW)	🟩	*Eucalyptus oblonga, Eucalyptus gummifera, Eucalyptus racemosa, Eucalyptus sieberi*	Ridges and upper slopes on Hawkesbury Sandstone with well-drained soil
Heath Woodland (HW)	🟦	*Eucalyptus haemastoma, Eucalyptus gummifera*	Broad damp ridgetops with ironstone mantle on Hawkesbury Sandstone
Ironstone Heath (IH)	🟫	*Angophora hispida, Hakea dactyloides* (multi-stemmed form)	Broad damp ridgetops with ironstone mantle on Hawkesbury Sandstone
Mallee Heath (MH)	🟪	*Eucalyptus luehmanniana, Eucalyptus gummifera*	Stony well-drained ridgetops on Hawkesbury Sandstone
Rock Pavement Heath (RPH)	🟨	*Kunzea ambigua, Darwinia fascicularis*	Skeletal soils on pavements of Hawkesbury Sandstone
Banksia Thicket (BT)	🟧	*Banksia ericifolia, Hakea teretifolia* (single-stemmed form)	Infrequently waterlogged soils on the margins of deposits of swamp alluvium
Sedgeland-Heath (SHM) Mosaic:	🟪		
Restioid Heath (RH)		*Banksia oblongifolia, Hakea teretifolia* (multi-stemmed form)	Occasionally waterlogged soils on small areas of swamp alluvium or on upper slopes of larger swamps
Sedgeland (SL)		*Sprengelia incarnata, Bauera microphylla, Symphionema paludosum*	Occasionally waterlogged soils on seepage slopes perched on Sandstone benches or the upper slopes of large swamps
Cyperoid Heath (CH)		*Banksia robur, Hakea teretifolia* (multi-stemmed form), *Leptospermum juniperinum*	Frequently waterlogged organic soils in seepage zones on swamp alluvium
Ti-tree Thicket (TT)	🟪	*Leptospermum juniperinum, Leptospermum grandifolium, Epacris paludosa, Banksia robur*	Heavily waterlogged peaty soils along drainage lines in large deposits of swamp alluvium
Disturbed Land (D)	⬜	Agricultural and industrial land (in active use or abandoned and regenerating)	

Grid - Australian Map Grid shown at intervals of 1 000 m

━	Creeks
━	Sealed Roads
▬ ▬	Unsealed Roads and Fire Trails



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VEGETATION
of the
O'HARES CREEK
CATCHMENT

WOLLONGONG DISTRICT
NEW SOUTH WALES

D.A. Keith

Produced by M. G. Tozer,
NSW National Parks and Wildlife Service to accompany
CUNNINGHAMIA VOLUME 3 NUMBER 3, 1994.
Royal Botanic Gardens Sydney

NATIVE FLORA OF THE O'HARES CREEK CATCHMENT

To accompany: Floristics, structure and diversity of natural vegetation in the O'Hares Creek catchment, south of Sydney by David Keith, 1994. Nomenclature follows Harden (1990, 1991, 1992, 1993).

PTERIDOPHYTES

ADIANTACEAE
Adiantum aethiopicum
Adiantum hispidulum
Cheilanthes distans
Cheilanthes sieberi ssp. sieberi

ASPLENIACEAE
Asplenium flabellifolium

BLECHNACEAE
Blechnum ambiguum
Blechnum cartilagineum
Blechnum nudum

CYATHEACEAE
Calochlaena dubia
Cyathea australis

DAVALLIACEAE
Davallia pyxidata

DENNSTAEDTIACEAE
Histiopteris incisa
Pteridium esculentum

GLEICHENIACEAE
Gleichenia dicarpa
Gleichenia microphylla
Gleichenia rupestris
Sticherus flabellatus

GRAMMITIDACEAE
Grammitis billardieri

HYMENOPHYLLACEAE
Hymenophyllum cupressiforme

LINDSAEACEAE
Lindsaea linearis
Lindsaea microphylla

LYCOPODIACEAE
Lycopodium deuterodensum
Lycopodium laterale

OSMUNDACEAE
Todea barbara

POLYPODIACEAE
Platcerium bifurcatum ssp. bifurcatum

SCHIZAEACEAE
Schizaea bifida

SELAGINELLACEAE
Selaginella uliginosa

GYMNOSPERMS

CUPRESSACEAE
Callitris endlicheri
Callitris muelleri
Callitris rhomboidea

DICOTYLEDONS

ACANTHACEAE
Brunoniella pumilio

APIACEAE
Actinotus helianthi
Actinotus minor
Centella asiatica
Hydrocotyle acutiloba
Hydrocotyle peduncularis
Platysace ericoides
Platysace lanceolata
Platysace linearifolia
Xanthosia dissecta
Xanthosia pilosa
(dentate form)
(dissected form)
Xanthosia tridentata

ARALIACEAE
Astrotricha latifolia
Polyscias sambucifolia

ASCLEPIADACEAE
Marsdenia suaveolens
Tylophora barbata

ASTERACEAE
Cassinia aculeata
Cassinia aureonitens
Cassinia denticulata
Gnaphalium gymnocephalum
Helichrysum elatum
Helichrysum scorpioides
Lagenifera stipitata
Olearia erubescens
Olearia microphylla
Olearia viscidula
Ozothamnus diosmifolius
Senecio apargiifolius
Senecio hispidulus var. hispidulus
Senecio minimus var. minimus
Vernonia cinerea var. cinerea

BAUERACEAE
Bauera microphylla
Bauera rubioides

CAMPANULACEAE
Wahlenbergia gracilis

CASSYTHACEAE
Cassytha glabella
Cassytha pubescens

CASUARINACEAE
Allocasuarina distyla
Allocasuarina littoralis
Allocasuarina nana
Allocasuarina paludosa

CHLOANTHACEAE
Chloanthes stoechadis

CUNONIACEAE
Callicoma serratifolia
Ceratopetalum apetalum
Ceratopetalum gummiferum
Schizomeria ovata

DILLENIACEAE
Hibbertia dentata
Hibbertia empetrifolia
Hibbertia fasciculata
Hibbertia monogyna
Hibbertia nitida
Hibbertia riparia
Hibbertia scandens
Hibbertia serpyllifolia

DROSERACEAE
Drosera binata
Drosera peltata
Drosera pygmaea
Drosera spathulata

ELAEOCARPACEAE
Elaeocarpus reticulatus

EPACRIDACEAE
Acrotriche divaricata
Astroloma humifusum
Astroloma pinifolium
Brachyloma daphnoides var. daphnoides
Dracophyllum secundum
Epacris crassifolia
Epacris coriacea
Epacris longiflora
Epacris microphylla
Epacris obtusifolia
Epacris paludosa
Epacris pulchella
Leucopogon amplexicaulis
Leucopogon ericoides
Leucopogon esquamatus
Leucopogon exolasius
Leucopogon lanceolatus var. lanceolatus
Leucopogon microphyllus
Leucopogon virgatus
Lissanthe strigosa
Melichrus urceolatus
Monotoca ledifolia
Monotoca scoparia
Sprengelia incarnata
Styphelia triflora
Styphelia tubiflora
Woollsia pungens

EUPHORBIACEAE
Amperea xiphoclada
Bertya pomaderroides
Micrantheum ericoides
Micrantheum hexandrum
Monotaxis linifolia
Phyllanthus hirtellus
Poranthera corymbosa
Poranthera ericifolia
Poranthera microphylla
Pseudanthus orientalis
Pseudanthus pimelioides
Ricinocarpos pinifolius

FABACEAE
Acacia binervata
Acacia hispidula
Acacia bynoeana
Acacia elongata
Acacia irrorata ssp. irrorata
Acacia linifolia
Acacia longifolia var. longifolia
Acacia myrtifolia
Acacia obtusifolia
Acacia rubida
Acacia stricta
Acacia suaveolens
Acacia terminalis
Acacia ulicifolia
Almaleea paludosa
Aotus ericoides
Bossiaea ensata
Bossiaea heterophylla
Bossiaea obcordata
Bossiaea prostrata
Bossiaea rhombifolia ssp. rhombifolia
Daviesia acicularis
Daviesia alata
Daviesia corymbosa
Daviesia ulicifolia
Desmodium varians
Dillwynia floribunda var. floribunda
Dilwynnia retorta var. retorta
Glycine clandestina
Glycine tabacina
Gompholobium glabratum
Gompholobium grandiflorum
Gompholobium latifolium
Gompholobium minus
Hardenbergia violacea
Hovea linearis
Kennedia prostrata var. prostrata
Kennedia rubicunda
Mirbelia rubiifolia
Mirbelia speciosa
Oxylobium cordifolium
Oxylobium ilicifoliom
Phyllota phylicoides
Pultenaea aristata
Pultenaea blakelyi
Pultenaea daphnoides
Pultenaea divaricata
Pultenaea elliptica
(yellow-flowered form)
(red-flowered form)
Pultenaea flexilis
Pultenaea hispidula
Pultenaea linophylla
Pultenaea scabra var. scabra
Pultenaea stipularis
Sphaerolobium vimineum
Viminaria juncea

GERANIACEAE
Pelargonium inodorum

GOODENIACEAE
Dampiera purpurea
Dampiera stricta
Goodenia belledifolia
Goodenia dimorpha var. angustifolia
Goodenia hederacea ssp. hederacea
Goodenia heterophylla
Scaevola ramosissima var. ramosissima

HALORAGACEAE
Gonocarpus micranthus ssp. micranthus
Gonocarpus salsoloides
Gonocarpus tetragynus
Gonocarpus teucrioides

HYPERICACEAE
Hypericum gramineum

LAMIACEAE
Hemigenia purpurea
Prostanthera linearis
Westringia longifolia

LENTIBULARIACEAE
Utricularia dichotoma
Utricularia lateriflora

LOBELIACEAE
Lobelia dentata
Pratia purpurascens

LOGANIACEAE
Logania albiflora
Mitrasacme paludosa
Mitrasacme polymorpha

LORANTHACEAE
Amyema pendulum
Muellerina eucalyptoides

MELIACEAE
Synoum glandulosum

MENYANTHACEAE
Villarsia exaltata

MORACEAE
Ficus rubiginosa

MYRSINACEAE
Rapanea variabilis

MYRTACEAE
Angophora costata
Angophora hispida
Backhousia myrtifolia
Baeckea brevifolia
Baeckea densifolia
Baeckea diosmifolia
Baeckea imbricata
Baeckea linifolia
Baeckea ramosissima ssp. ramosissima
Callistemon citrinus
Callistemon linearis
Calytrix tetragona
Darwinia diminuta
Darwinia fascicularis ssp. fascicularis
Darwinia grandiflora
Eucalyptus agglomerata
Eucalyptus apiculata
Eucalyptus consideniana
Eucalyptus globoidea
Eucalyptus gummifera
Eucalyptus haemastoma
Eucalyptus ligustrina
Eucalyptus luehmanniana
Eucalyptus multicaulis
Eucalyptus oblonga
Eucalyptus obstans
Eucalyptus pilularis
Eucalyptus piperita ssp. piperita
Eucalyptus punctata
Eucalyptus racemosa
Eucalyptus saligna
Eucalyptus sieberi
Eucalyptus stricta
Kunzea ambigua
Kunzea capitata
Leptospermum arachnoides
Leptospermum continentale
Leptospermum grandifolium
Leptospermum juniperinum
Leptospermum morrisonii
Leptospermum parvifolium
Leptospermum polygalifolium
Leptospermum squarrosum
Leptospermum trinervium
(broad-leaved form)
(narrow-leaved form)
Melaleuca deanei
Melaleuca linariifolia
Melaleuca squamea
Melaleuca squarrosa
Melaleuca thymifolia
Tristania neriifolia
Tristaniopsis collina
Tristaniopsis laurina

OLACACEAE
Olax stricta

OLEACEAE
Notelaea longifolia

OXALIDACEAE
Oxalis perennans

PITTOSPORACEAE
Billardiera procumbens
Billardiera scandens
Bursaria spinosa

POLYGALACEAE
Comesperma defoliatum
Comesperma ericinum
Comesperma retusum
Comesperma volubile

PROTEACEAE
Banksia cunninghamii ssp. cunninghamii
Banksia ericifolia
Banksia marginata
Banksia oblongifolia
Banksia paludosa
Banksia robur
Banksia serrata
Banksia spinulosa var. spinulosa
Conospermum ellipticum
Conospermum longifolium ssp. angustifolium
Conospermum taxifolium
Conospermum tenuifolium
Grevillea buxifolia
Grevillea diffusa ssp. diffusa
Grevillea longifolia
Grevillea mucronulata
Grevillea oleoides
Grevillia parviflora
Grevillea sphacelata
Hakea dactyloides
(single-stemmed form)
(multi-stemmed form)
Hakea gibbosa
Hakea propinqua
Hakea salicifolia
Hakea sericea
Hakea teretifolia
(single-stemmed form)
(multi-stemmed form)
Isopogon anemonifolius
Isopogon anethifolius
Lambertia formosa
Lomatia myricoides
Lomatia silaifolia
Persoonia lanceolata
Persoonia laurina
Persoonia levis
Persoonia linearis
Persoonia mollis ssp. nectans
Persoonia pinifolia
Petrophile pedunculata
Petrophile pulchella
Petrophile sessilis
Stenocarpus salignus
Symphionema paludosum
Telopea speciosissima
Xylomelum pyriforme

RANUNCULACEAE
Clematis aristata

RHAMNACEAE
Cryptandra ericoides
Pomaderris andromedifolia
Pomaderris intermedia
Pomaderris lanigera

RUBIACEAE
Galium binifolium
Opercularia aspera
Opercularia varia
Pomax umbellata

RUTACEAE
Boronia floribunda
Boronia ledifolia
Boronia parviflora
Boronia serrulata
Correa reflexa var. reflexa
Eriostemon australasius ssp. australasius
Eriostemon scaber ssp. scaber
Phebalium dentatum
Phebalium diosmeum
Phebalium squamulosum ssp. squamulosum
Phebalium squameum ssp. squameum
Zieria cytisoides
Zieria laevigata
Zieria smithii

SANTALACEAE
Choretrum candollei
Exocarpos cupressiformis
Exocarpos strictus
Leptomeria acida
Santalum obtusifolium

SAPINDACEAE
Dodonaea multijuga
Dodonaea triquetra

SCROPHULARIACEAE
Euphrasia collina ssp. speciosa

STACKHOUSIACEAE
Stackhousia nuda
Stackhousia viminea

STERCULIACEAE
Lasiopetalum macrophyllum
Lasiopetalum ferrugineum var. ferrugineum

STYLIDIACEAE
Stylidium graminifolium
Stylidium laricifolium
Stylidium lineare
Stylidium productum

THYMELAEACEAE
Pimelea linifolia

TREMANDRACEAE
Tetratheca neglecta
Tetratheca shiressii

VIOLACEAE
Hybanthus monopetalus
Viola betonicifolia
Viola hederacea
Viola sieberiana

MONOCOTYLEDONS

AGAVACEAE
Doryanthes excelsa

ANTHERICACEAE
Caesia parviflora
Caesia vittata
Laxmannia gracilis
Sowerbaea juncea
Thysanotus juncifolius
Thysanotus tuberosus
Tricoryne elatior
Tricoryne simplex

ARECACEAE
Livistona australis

BLANDFORDIACAE
Blandfordia nobilis

CENTROLEPIDACEAE
Centrolepis strigosa

COLCHICACEAE
Burchardia umbellata

CYPERACEAE
Baumea acuta
Baumea gunnii
Baumea nuda
Baumea rubiginosa
Baumea teretifolia
Caustis flexuosa
Caustis pentandra
Caustis recurvata
Chorizandra cymbaria
Chorizandra sphaerocephala
Cyathochaeta diandra
Eleocharis sphacelata
Gahnia clarkei
Gahnia radula
Gahnia sieberiana
Gymnoschoenus sphaerocephalus
Lepidosperma filiforme
Lepidosperma flexuosa
Lepidosperma forsythii
Lepidosperma laterale
Lepidosperma limicola
Lepidosperma lineare
Lepidosperma neesii
Lepidosperma squamatum
Lepidosperma tortuosum
Lepidosperma urophorum
Lepidosperma viscidum
(red-gummed form)
(clear gummed form)
Ptilanthelium deustum
Schoenus apogon
Schoenus brevifolius
Schoenus ericetorum
Schoenus maschalinus
Schoenus melanostachys
Schoenus moorei
Schoenus pachylepis
Schoenus paludosus
Schoenus turbinatus
Schoenus villosus
Tetraria capillaris
Tricostularia pauciflora

HAEMODORACEAE
Haemodorum corymbosum
Haemodorum planifolium

HYPOXIDACEAE
Hypoxis hygrometrica

IRIDACEAE
Patersonia glabrata
Patersonia sericea
Patersonia sp. aff. fragilis

JUNCACEAE
Juncus planifolius

JUNCAGINACEAE
Triglochin procera

LOMANDRACEAE
Lomandra cylindrica
Lomandra filiformis ssp. coriacea
Lomandra filiformis ssp. filiformis
Lomandra fluviatilis
Lomandra glauca ssp. glauca
Lomandra gracilis
Lomandra longifolia ssp. longifolia
Lomandra multiflora
Lomandra obliqua

ORCHIDACEAE
Acianthus fornicatus var. fornicatus
Caladenia caerulea
Caladenia carnea
Caleana major
Chiloglottis reflexa
Corybas fordhamii
Cryptostylis erecta
Cryptostylis subulata
Dendrobium linguiforme var. linguiforme
Dendrobium speciosum var. speciosum
Dipodium punctatum
Genoplesium nublingii
Glossodia minor
Liparis reflexa
Microtis ?unifolia
Orthoceras strictum
Paracaleana minor
Prasophyllum australe
Prasophyllum brevilabre
Prasophyllum elatum
Pterostylis curta
Pterostylis grandiflora
Pterostylis longifolia
Pterostylis parviflora
Thelymitra circumsepta

PHILESIACEAE
Eustrephus latifolius var. latifolius

PHORMIACEAE
Dianella caerulea
Dianella revoluta
Thelionema caespitosum
Thelionema umbellatum

POACEAE
Amphipogon strictus var. strictus
Anisopogon avenaceus
Aristida vagans
Aristida warburgii
Chionochloa pallida
Danthonia longifolia
Danthonia tenuior
Deyeuxia decipiens
Deyeuxia quadriseta
Dichelachne micrantha
Dichelachne rara
Echinopogon ovatus
Entolasia marginata
Entolasia stricta
Eragrostis brownii
Eriachne glabrata
Hemarthria uncinata var. uncinata
Imperata cylindrica var. major
Microlaena stipoides var. stipoides
Oplismenus imbecillus
Panicum simile
Phragmites australis
Plinthanthesis paradoxa
Poa labillardieri var. labillardieri
Stipa pubescens
Tetrarrhena turfosa
Themeda australis

RESTIONACEAE
Empodisma minus
Hypolaena fastigiata
Leptocarpus tenax
Lepyrodia anarthria
Lepyrodia gracilis
Lepyrodia scariosa
Restio complanatus
Restio dimorphus
Restio fastigiatus
Restio gracilis
Restio tetraphyllus ssp. meiostachyus

SMILACACEAE
Smilax glyciphylla

XANTHORRHOEACEAE
Xanthorrhoea arborea
Xanthorrhoea concava
Xanthorrhoea media
Xanthorrhoea resinifera (tall scape form)
Xanthorrhoea resinifera (short scape form)

XYRIDACEAE
Xyris gracilis ssp. laxa
Xyris juncea
Xyris operculara
Xyris ustulata

NON-INDIGENOUS FLORA OF THE O'HARES CREEK CATCHMENT

Taxa marked "+" are Australian natives unlikely to be indigenous to the area or particular habitats and proliferating in disturbed sites. Localities examined: EI - Effluent Irrigation Site, south of Darkes Forest Mine; GP - Rehabilitated Gravel Pit, No. 10 Fire Road; DF - Darkes Forest, farmland interface; CQ - Abandoned Clay Quarry; FT - Fire Trails (mostly 10B, 10C & No. 10); SS - Survey Sample in undisturbed vegetation; NC - North Cliff mine site.

GYMNOSPERMS

PINACEAE
Pinus radiata DF

DICOTYLEDONS

ASTERACEAE
Ageratina adenophora EI
Cirsium vulgare EI
Conyza albida EI DF FT SS
Facelis retusum GP
Gnaphalium americanum EI GP
+Gnaphalium gymnocephalum EI
Hypochoeris glabra DF EI
Hypochoeris radiata EI GP DF SS
+Pseudognaphalium luteo-album GP
Senecio madagascariensis EI DF

APIACEAE
+Hydrocotyle tripartita EI

CARYOPHYLLACEAE
Polycarpon tetraphyllus GP

FABACEAE
+Acacia binervia FT
+Acacia decurrens DF
+Acacia mearnsii DF
Trifolium dubium DF
Trifoium repens EI
Ulex europaceus DF
Vicia angustifolia DF

GENTIANACEAE
Centaurium erythreum EI

GERANIACEAE
+Geranium solanderi

ONAGRACEAE
+Epilobium billardieranum EI
Oenothera rosea EI

POLYGONACEAE
Persicaria sp. EI

ROSACEAE
Rubus ?discolor DF SS

MONOCOTYLEDONS

CYPERACEAE
Cyperus brevifolius
Cyperus ?eragrostis

IRIDACEAE
Romulea rosea GP
Watsonia angusta DF

JUNCACEAE
Juncus articulatus EI NC
Juncus cognatus EI FT
+Juncus continuus EI FT
+Juncus planifolius EI FT
+Juncus ?polyanthemus EI

POACEAE
+Agrostis ?avenacea EI
Andropogon virginicus EI FT DF
Cortaderia seloana EI
+Cynodon dactylon DF GP
+Danthonia longifolia FT
+Digitaria parviflora EI
Echinochloa frumentacea GP
+Eragrostis brownii FT
Eragrostis sp. EI
Holcus lanatus EI
Lolium perenne DF
Paspalum dilatatum EI
Pennisetum clandestinum DF CQ
Setaria gracilis EI
Vulpia bromioides GP

CUNNINGHAMIA

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The natural vegetation of north-western New South Wales: notes to accompany the 1:1 000 000 vegetation map sheet
John Pickard and E.H. Norris 423

Rainforest stands between Barrington Tops and the Hunter River, New South Wales **J.C. Turner and S.L. Vernon** 465

Observations on the effects of mowing on native species in remnant bushland, western Sydney **T.A. James** 515

The effect of time since fire on the cover and composition of cryptogamic soil crusts on a eucalypt shrubland soil
D.J. Eldridge and R.A. Bradstock 521

Lost and found: *Nothofagus moorei* at Comboyne
C.L. Bale and J.B. Williams 529

Observations on the ecology and conservation status of the rare herb *Gentiana wingecarribiensis*
P.G. Kodela, T.A. James and P.D. Hind 535

Floristics, structure and diversity of natural vegetation in the O'Hares Creek catchment, south of Sydney **David Keith** 543

Performance of halophytes from semi-arid areas on two saline seepage scalds of the Central West Slopes of NSW
W.S. Semple and D. Waterhouse 595

The native grasslands of the Monaro region: Southern Tablelands of NSW **J.S. Benson** 609

Plant communities of the Monaro lakes
J.S. Benson and S.W.L. Jacobs 651

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